
U.S. DEPARTMENT OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY

-

A Summary of Current Program 7/1/65

and Preliminary Report of Progress

for 7/1/64 to 6/30/65

ENTOMOLOGY RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

Section A

This progress report is primarily a tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between July 1, 1964, and June 30, 1965. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.

July 1, 1965

TABLE OF CONTENTS

INTRODUCTION

Entomology research is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugarbeets, and ornamental crops; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many finds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at almost 7 billion dollars annually.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological, and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits to provide specific methods of control for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has work located at 63 field locations in the United States, 6 locations in foreign countries, and one in Puerto Rico. Of the total professional staff of 430, 118 are located at the Agricultural Research Center, Beltsville, Md., or at Washington, D. C. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Departments of Defense, State, Interior, and Health, Education and Welfare, Atomic Energy Commission, World Health Organization, and the International Atomic Energy Agency.

The Division sponsors 73 domestic research projects through grants, contracts, and cooperative agreements negotiated with State experiment stations, universities, boards of health, and independent laboratories throughout the United States.

The Division also sponsors 56 research projects in 13 foreign countries financed under the Public Law 480 program for utilizing foreign currencies received in payment for excess agricultural products from the United States. Research is conducted under agreements with the Agency for International Development in Rhodesia, Africa, Karaj, Iran, and San Jose, Costa Rica.

A broad analysis of the Division's research by different approaches to insect control shows that about 20 percent of the current effort is on the conventional chemical approach to insect control; 12 percent on biological control (parasites, predators, and pathogens); 7 percent on plant resistance to insects; 26 percent on the sterility and other new approaches to insect control such as natural attractants; and 35 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases. Substantial changes in the research effort have been made in the

last 7 years, largely by shifts within available funds, to place more emphasis on nonchemical or on special chemical approaches to insect control.

A few examples of recent outstanding developments in the research of the Entomology Research Division indicating the continuing value of basic and applied entomological research to the Nation's agriculture and general welfare follow:

Low volume sprays effective for a wide range of insects. Research was continued in 1964 and 1965 to determine the potential value of insecticide sprays when applied as low volume treatments from aircraft. Undiluted technical malathion applications by aircraft with specially designed nozzles are being utilized in Federal-State cooperative programs for control of grasshoppers; boll weevil, and cereal leaf beetle. Research on grasshoppers showed that increased efficiency in low volume sprays was not limited to malathion. Good results were also obtained with low volume formulations of diazinon, naled, and carbaryl. Low volume spray formulations of malathion, parathion, and fenthion provided good control of mosquitoes in experimental applications. Studies have shown that insecticide deposits in the target area are higher with aircraft sprays of concentrates than with comparable amounts in dilute formulations.

Nuclear polyhedrosis virus promising for control of bollworm-tobacco budworm complex on cotton. Field evaluations of a bollworm polyhedrosis virus at a dosage of 100 diseased larvae per acre provided control as effective as 2 pounds of toxaphene plus 1 pound of DDT at Brownsville, Texas; 2 pounds of carbaryl at Waco, Texas; and 1 pound of DDT at Tallulah, Louisiana. Studies on mammalian toxicology are being continued to develop information which will permit registeration of insect viruses for practical use in insect control. Studies on mass production of several insect virus diseases are continuing.

Alfalfa weevil parasites established and spreading. The alfalfa weevil is continuing to spread in the eastern United States. Foreign parasite explorations have provided the importation of several species of parasites of this important introduced pest of alfalfa. Four of the species of parasites introduced are now established and spreading at one or more locations. Parasite releases have been made in Vermont, New York, Ohio, Indiana, and Missouri.

Natural sex attractant of pink bollworm employed in regulatory detection program. Methods have been developed for rearing large numbers of pink bollworm moths and for the preparation of extracts from the virgin females that are strong male attractants. Extracts supplied to the Plant Pest Control Division in 1964 and 1965 have been utilized successfully in surveys to detect incipient infestations. Studies to develop methods of utilizing this strong attractant in control are being continued. Chemical investigations have determined the structure of the active component of the attractant and research is under way to synthesize it.

AREA NO. 1. VEGETABLE INSECTS

Problem. The major objective of this research is to develop more effective, economical, and less objectionable methods of controlling insect and mite pests of vegetables in the field without leaving undesirable residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, or adversely affecting beneficial insects. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating animal products by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into non-target areas also causes problems. Another difficulty is that a number of vegetable insects have developed resistance to certain insecticides. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects and mites; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; evaluation of insecticide application equipment; and the practical integration of non-chemical and chemical methods in area control of vegetable insect and mite pest populations. Additional emphasis should be placed on research to develop vegetable crops resistant to insects and to determine the factors involved in resistance when found. Research is needed on insect vectors of vegetable diseases and the role they play in the dissemination of viruses. The heavy loss of corn due to corn stunt and maize dwarf mosaic recently in the Southern and North Central States indicates the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz., Riverside, Calif., Tifton, Ga., Twin Falls, Idaho, Lafayette, Ind., Baton Rouge, La., Beltsville, Md., State College, Miss., Wooster, Ohio, Forest Grove, Oreg., Charleston, S.C., Logan, Utah, and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Work in Louisiana is under contract to the Louisiana Agricultural Experiment Station. Some of the work in Indiana is done by grant to the Agricultural Experiment Station.

Work was initiated in Karaj, Iran, on insects affecting vegetable legumes with funds supplied by the Agency for International Development (AID) under the grain legume production project in cooperation with the Crops Research Division, the Soil and Water Conservation Research Division, Karaj Agricultural College, the Iran Ministry of Agriculture and the Iran Plan Organization.

The Federal scientific effort devoted to research in this area totals 28.0 professional man-years. Of this number 4.0 is devoted to basic biology, physiology, and nutrition; 4.8 to insecticidal and cultural control; 3.7 to insecticide residue determination; 5.4 to biological control; 2.0 to insect sterility, attractants, and other new approaches to control; 1.5 to evaluation of equipment for insect detection and control; 4.0 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.3 to program leadership.

In addition Federal support of research in this area under contracts and grants provides 1.7 man-years. Of this total, 0.3 is devoted to insecticidal and cultural control; 0.2 to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; and 0.6 to varietal evaluation for insect resistance.

PROGRAM OF STATE EXPERIMENT STATIONS

Research on vegetable insects at the State experiment stations is designed to provide both basic and applied information. Emphasis is being placed on developing methods for reducing the number of insecticide applications required for control. Population levels of injurious species necessary to cause economic damage are being determined. Insect predators and parasites are under investigation to determine what practices contribute to their increase. Microorganisms pathogenic to insects such as the polyhedrosis virus of the cabbage looper are being evaulated for their effectiveness. Fundamental studies on the influence of environmental factors on diapause, movement, and population size of injurious insects are being performed as methods for laboratory rearing of insects become more refined. Plant resistance and strip-planting of vegetables with other crops are promising areas under investigation. Methods of insecticide application which reduce the amount of chemical applied directly to the plant and the development of insecticides with greatly reduced residual properties are important current research areas. Studies also are being performed on the insect transmission of vegetable diseases.

The total State scientific effort devoted to vegetable insect research is 45.3 professional man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Cabbage Looper Population Density and Migration Studies. The numbers of

cabbage looper moths caught in blacklight traps at Riverside, Calif., were low from November to mid-June. There followed a rapid rise to a peak catch of 31 moths per night per trap in August and a gradual decline thereafter to November. The male to female ratios of moths trapped varied considerably during the season, but the total catch was 53% males and 46% females. In general the number of matings per female increased as the proportion of males to females in the trapped samples increased. For the entire year females mated approximately 1.27 times but some mated as many as 6 times. Sixty-six percent of all female moths trapped during the year had mated at least once and 35% of these more than once. Male moths were trapped in greater abundance from midnight to 6 a.m. than from 6 p.m. to midnight. The reverse was true for females. The efficiency of blacklight traps in attracting cabbage looper males was increased from 12 to 37 times by virgin females of the species placed in cages adjacent to or in close proximity to the trap.

2. Flight Characteristics of Cabbage Looper Moths. A "flight mill" was successfully adapted for cabbage looper flight studies at Riverside, Calif. The equipment provides for automatic recording of the flight of moths fastened to a rotatable side arm. Total flight distance, time, and duration of flight and rest periods were determined. The flight distance of individual moths ranged from 0-120 miles. Maximum continuous flight time was approximately 7 hours during which the insect traveled 25 miles. The average velocity for all flying moths observed was 3 miles per hour with a maximum of 6 miles per hour. Moths 3 to 4 days old flew more consistently than moths 2 days old or less.

3. Salt Marsh Caterpillar Biology. Salt marsh caterpillars were reared on a modified semi-artificial medium successfully for 7 generations at Riverside, Calif. Pupation was over 90% for 3 generations, with 84 to 100% of the pupae producing normal moths, approximately 50% of which were females. Female pupae weighed more than male pupae. The viability of eggs from adults was low, ranging from 16 to 48%. Most matings occurred between approximately 3 a.m. and 5 a.m. Moth age was not a critical factor in determining mating and newly emerged to 4-day-old moths mated with equal frequency.

4. Adult Cabbage Looper Diets. At Riverside, Calif., moths fed 5, 10, or 15% aqueous solutions of galactose, dextrin, or lactose or 10% trehalose produced fewer eggs than moths fed solutions containing 5, 10, or 15% aqueous solutions of honey, levulose, dextrose, or sucrose. When moth pairs were fed maltose, the females laid more eggs than those fed sucrose; when fed honey solutions, the females deposited more eggs than those fed on other sugars. In general, moths did not produce more eggs nor was the viability increased with the higher sugar concentrations. However, moths fed 5% of dextrin or maltose laid fewer viable eggs than moths fed 10 or 15% dextrin or maltose. Moths fed 5% of galactose or dextrose laid more viable eggs than moths fed the higher concentrations of each sugar.

Longevities of male and female moths fed honey, levulose, dextrose, maltose, or sucrose were comparable at all concentrations. Moths fed any concentration of galactose, dextrin, lactose, or 10% trehalose were shorter lived than moths fed on other sugar solutions and in some cases they did not live as long as those fed water alone. When moth pairs were given only water, the females produced an average of 183 eggs per female, 52% were viable and longevity averaged 7 days. The females of moth pairs fed the more effective solutions of honey, levulose, dextrose, or sucrose laid from 419 to 642 eggs per female and lived 11 to 20 days.

5. Cabbage Looper Rearing Studies. At Riverside, Calif., at least 4 microbial contaminants were observed developing in the cabbage looper rearing medium where they reduced pupal yields. Formaldehyde, methyl p-hydroxybenzoate, n-butyl-p-hydroxybenzoate, sorbic acid, ottasept, pimaricin, vancomycin, and nystatin were evaluated as to their efficiency in reducing or eliminating contaminants on the medium and their effect on cabbage looper pupal yields and adult fecundity. Observations were made for at least 4 generations for each material tested. Microbial inhibitors must be effective for at least 14 days to be useful. Since each material was effective against some of the contaminants but not all of them, combinations of microbial inhibitors were necessary to effectively control all contaminants. The best antimicrobial combinations were n-butyl-p-hydroxybenzoate or methyl p-hydroxybenzoate (2,000 ppm in each case) plus sorbic acid (2,000 ppm). Combinations of ottasept (500 ppm) plus sorbic acid (2,000 ppm) or vancomycin (134 ppm) plus formaldehyde (370 ppm) were also effective in reducing mold contaminants for 14 days but may have retarded larval development.

Cabbage looper larvae were efficiently reared in 6- or 8-ounce paraffin-coated Lily cups. Approximately 24 larvae were reared per container at the total cost of about 0.3 cent per insect.

6. Mating Competitiveness Technique for Male Cabbage Looper Moths. In studies in California 11 water soluble fluorescent dyes were found that can be fed to male cabbage looper moths in sucrose solutions to make the spermatophores of the male easily identifiable in the female after mating. The dyes are Rhodamine B, methyl violet, eosin, Rhodamine 3 GO, Neutral Red Extra, pyronin, fluorescein, solium salt of fluorescein, brilliant phosphine, entozon, and primulin.

7. Caterpillar Pests of Leafy Vegetables in Arizona. At Mesa, Ariz., studies of flights of moths of the cabbage looper, alfalfa looper, beet armyworm, yellow-striped armyworm, corn earworm, and granulate cutworm are being continued on an annual basis by means of eight blacklight traps widely distributed within the cultivated area of the Salt River Valley and four similar traps in the desert areas surrounding cultivation. With the exception of the corn earworm, these noctuid moths have been taken in low but significant numbers throughout the entire year. Higher populations of noctuid moths occurred from January to March 1965 than for the same season in 1964. The difference in cabbage looper populations was far greater than

those for other noctuids. Winter rains germinated mustards in desert areas and indications were that a brood of cabbage loopers developed in the desert during January and February. From April to June populations of the cabbage looper were greater in the cultivated area than in the desert. During this period no known host plants of the looper occurred in the desert. These data indicate that the desert areas contributed cabbage looper moths to the cultivated areas only from January to March. Moths caught in desert traps later must have emerged in the cultivated area and moved out to the desert.

At Mesa, Ariz., marked moths were released periodically at 50, 100, and 200 feet from one 15-watt blacklight trap. Results showed that the recovery of cabbage looper moths dropped off rapidly between 50 and 100 feet with very few moths recovered at 200 feet. A greater percentage of beet armyworm moths than cabbage looper moths was recovered at 100 and 200 feet. Recoveries of armyworm moths were also comparatively low at 200 feet. These data indicate that the attractiveness of 15-watt BL to cabbage looper moths drops off rapidly between 50 and 100 feet but that the beet armyworm moths may be attracted to the light from a somewhat greater distance. Releases of marked moths in the four cardinal directions from one trap showed that although the moths flew in all directions there was a tendency for flight from south to north.

8. Blacklight Trap Study Area for the Cabbage Looper. Twenty-five 15-watt blacklight traps were installed over a 100 square mile study area southeast of Mesa, Ariz. These traps were placed at 2-mile intervals throughout the area and 16 points for release of marked looper moths were established at intervening locations. Rearing, marking, and releasing moths within this area to obtain basic data on flight behavior was commenced in June 1965. From the ratio of marked moths to native moths recovered, population estimates and flight behavior throughout the season will be derived. From these data, the feasibility of population suppression on an area basis may be indicated.

9. Southern Potato Wireworm. A total of 25,414 adults were caught in a single 15-watt BL trap operated throughout 1964 in coastal South Carolina. This constituted 98.4% of the total number of elaterid beetles taken. Conoderus falli composed 93% of larvae found in soil in 19 cultivated fields on 13 farms in October. Male sperms were found in females in spermatophores. Mating was observed during the afternoon. Very few adults were present or attracted to a BL trap in wooded areas. Only 6 beetles were taken in 3 traps located about 100 feet into woods between May 28 and June 21, as compared to 10,545 taken in 3 traps in nearby cultivated fields. Dipping of larvae in solutions of several proprietary tranquilizers, phenobarbital, and morphine sulfate and, in other tests, soaking the food in these solutions apparently did not reduce cannibalism among caged larvae.

10. Banded Cucumber Beetle. In South Carolina a feeding stimulant for the larvae was extracted from sweetpotato with water. The larvae preferred to feed on an agar-alphacel substrate containing a water extract of wheat germ

rather than on similar ones containing extracts of either corn meal, soybean meal, sweetpotato, or germinated corn kernels. A water-soluble substance that elicits a strong biting response in adults was extracted from 11 species of cucurbits (10 of Cucumis and 1 of Cucurbita), the most active extracts coming from Cucumis heptodoctylus and Cucumis ficefolius.

11. Sweetpotato Insects. Larvae of the banded cucumber beetle and the pale-striped flea beetle caused 71% of the insect injuries to sweetpotato in Louisiana in 1964. In cage studies much of the injury caused by these two species was indistinguishable. Relatively high populations of banded cucumber beetle larvae were found as late as mid-January 1965 and adults were abundant at this time. A survey of wireworm populations in sweetpotato soils disclosed that Conoderus vespertinus was the most abundant, followed by C. bellus and C. falli.

12. Sweet Corn Insects. At Tifton, Ga., a vitamin preparation commonly used in artificial diet for rearing lepidopterous larvae was found to be deficient in two vitamins, folic acid and vitamin B_{12}, when used in a fall armyworm diet. The substitution of another vitamin mixture containing the two vitamins in sufficient amounts has almost entirely eliminated insect deformities experienced in previous attempts to rear this insect. In addition, it has reduced the erratic and extended insect life cycle, increased the stability of the diet to breakdown by oxidation, increased production, and reduced costs (not only by the above factors, but also by reducing cannibalism which allows more insects to be produced with the same amount of labor and materials).

Entomologists in cooperation with agricultural engineers have developed two devices that facilitate the rearing of lepidopterous larvae on a large scale. One device uses air pressure to dispense large quantities of agar-base insect diet into individual rearing containers. The second is a machine that transports containers of insect diet beneath a venturi component where larvae are picked up and deposited onto the diet.

Research on the theory that insects locate and communicate by means of infrared and microwave radiation has continued at Tifton, Ga. Experiments with flight activity of noctuid moths under different lighting conditions have shown that mating is highest with ultraviolet and cool-daylight fluorescent lights alternating with darkness. The results indicate that conditioning the insects with ultraviolet and visible radiation contribute to their efficiency in receiving infrared and microwave radiation in darkness.

An infrared blackbody was constructed which eliminated all visible light but allowed radiation of secondary emission in the 8 μ to 13 μ region. Six different species of noctuid moths were attracted to the radiating blackbody in a totally dark room, whereas nonemitting blackbody controls did not attract any moths.

13. Pea and Bean Insects. In experimental plantings of vegetable legumes initiated at Karaj, Iran, the pea aphid was one of the first insects to cause injury, followed by the dipterous leaf miner, the pea weevil, the beet armyworm, and the corn earworm. The green peach aphid was also present. Pea varieties Ride de Knight and Morses Progress showed some evidence of resistance to the pea aphid.

B. Insecticidal and Cultural Control

1. Corn Earworm in Sweet Corn. When 19 sweet corn varieties were treated with five applications of DDT at 2 pounds per acre and graded for corn earworm damage at Tifton, Ga., little improvement was shown in insect control in varieties known to be resistant. The most susceptible varieties showed the greatest responses to DDT. Each of the following compounds applied at 1 pound per acre gave corn earworm control as good or better than 2 pounds of DDT per acre: SD-9129 and SD-8447, Mobil Oil MCA-600, Niagara NIA-10242, UpJohn U-12927, Stauffer R-5092, and General Chemical GS-4072.

2. Beet Leafhopper. Dimethoate and mevinphos continued to reduce the incidence of curly top in small field plots of beans in Idaho and increased yields. By caging viruliferous leafhoppers on the plants it was demonstrated that mevinphos was the more effective 1 day after application but that dimethoate is more effective 7 and 14 days after application. In laboratory tests with 68 materials, promising results were also obtained with Zinophos, Perthane, and 4 experimental insecticides.

In experimental plots of tomatoes at Farmington, Utah, mevinphos or Di-Syston granules added to the row at the rate of 4 pounds per acre at the time of transplanting reduced curly top 75% over the untreated checks.

At Santa Clara, Utah, experimental plots of tomato transplants receiving five foliar applications of dimethoate emulsion at the rate of 1 pound per acre showed 86% less curly top than the untreated checks. Dimethoate granules added to the plant holes at the time of transplanting reduced curly top 50% in curly-top-susceptible varieties and 88% in curly-top-resistant varieties.

3. Wireworms. In Washington 90% of sugarbeet wireworms confined in soils treated with 4 pounds per acre of parathion or diazinon (in granules) died within 14 days. In field experiments broadcast applications of granular diazinon or parathion at recommended dosages were usually effective against the sugarbeet wireworm, the Pacific coast wireworm, and the Great Basin wireworm, but control was more consistent with parathion than diazinon.

4. Sweetpotato Insects. In Louisiana plastic mulch barriers reduced insect injury to the roots of sweetpotato by approximately 20% but tended to increase injury caused by the sweetpotato weevil. Banded cucumber beetle larvae caused more damage to sweetpotatoes growing in fertilized than in unfertilized soil.

In South Carolina field experiments, diazinon and Stauffer N-2790 gave the most effective control of an insect complex consisting of the southern potato wireworm, the banded cucumber beetle, the spotted cucumber beetle, the elongate flea beetle, a related flea beetle (Systena frontalis) and an Anthicid (Notoxus calcaratus). Next best control was provided by a preplanting broadcast application of DDT. About 50% of the damage was caused by the wireworm.

In the laboratory in South Carolina, 39 experimental insecticides were screened against the banded cucumber beetle and 28 against the southern potato wireworm. Several of these materials have continued to show promise in field tests against wireworms. Laboratory tests revealed that larvae of southern potato wireworm developed approximately 4-fold resistance to parathion in the field between 1960 and 1964. No change in susceptibility to DDT or diazinon was apparent. Parathion and diazinon were as toxic to larvae of the gulf wireworm as to those of the southern potato wireworm in laboratory evaluations.

5. Dichlorvos Granules. Experimental granules of dichlorvos, prepared by impregnating corncobs or coarse vermiculite, retained activity for 42 months more efficiently than granules prepared on fine vermiculite, Attapulgite, or Diatomite. The fresh granules were equally toxic to drosophila, the green peach aphid, mealy bugs, and spider mites in these Maryland studies.

C. Insecticide Residue Determination

1. Undiluted Technical Malathion Spray. Laboratory tests at Beltsville with malathion (technical) applied undiluted in comparison with oil solution and water emulsion, each with 8 ounces malathion per acre, showed highest initial deposits (6 mg/cm^2) and longest persistency (0.5 mg at 12 or 15 days) from the undiluted technical material. Initial deposits from malathion in oil and malathion emulsion were lower (4.5 mg/cm^2) and had shorter persistency (0.5 mg in 4 days). In field tests with low volume sprays on spinach near Vienna, Md., undiluted technical malathion applied with the Yoeman nozzle persisted for 4 days with 1.8 ppm residue from 8 ounces per acre and 37 to 61 ppm residue from 16 ounces. Malathion from conventional emulsion spray applied at the same dosages completely disappeared during the 4-day period.

2. Diazinon on Greenhouse Tomatoes. In Maryland a spray prepared from a 25% diazinon emulsion concentrate was applied at the rate of 1 pound per acre. Samples of tomatoes collected the same day they were sprayed contained 0.43 ppm of diazinon. The residue decreased to 0.37 ppm by the second day and to less than 0.2 ppm by the fourth day after treatment.

3. Chlordane Residues from Soil Treatments. In Maryland, chlordane was applied to sassafras sandy loam soil at $1\frac{1}{4}$, $2\frac{1}{2}$, 5, and 10 pounds per acre before planting 10 vegetable crops. This range included all dosages recommended for all soil pests. Strawberries, tomatoes, and snap beans grown in this soil had residues of less than 0.01 ppm, which is the minimum

detectable level. Turnips, turnip tops, table beet tops, cantaloup, sweetpotatoes, Irish potatoes, and lettuce contained residues between 0.01 and 0.1 ppm. Beets and cucumbers grown in soil treated with 10 pounds of chlordane per acre contained residues of 0.15 and 0.11 ppm, respectively. Soil samples collected 127 days after treatment contained 0.16, .33, .58, and 1.1 ppm of chlordane for the different dosages, respectively.

4. Residues in Sweetpotato. Analyses by ARS chemists in Maryland showed no excessive residues of aldrin or dieldrin on or in roots of sweetpotato grown in South Carolina in field plots that received the following treatments: Dieldrin at 1.5 and at 3.0 lb/acre prior to planting; dieldrin at total of 1.6 lb/acre in 2 applications at base of plants during root enlargement; chlordane at 5 lb/acre prior to planting. Dieldrin residues ranged from 0.01 to 0.04 ppm and chlordane from 0.03 to 0.11 ppm.

Granular diazinon applied to the soil in sweetpotato plots at 3 pounds per acre once or twice during the period of root enlargement did not result in measurable residues in harvested sweetpotatoes.

5. On Sweet Corn. Entomologists and chemists at Tifton, Ga., determined residues of Shell SD-8447 applied to sweet corn as a wettable powder at $\frac{1}{2}$, 1, and 2 pounds per acre. Electron affinity gas chromatography analysis revealed that initial residues on the stalks and leaves were about the same as those on ear husks. However, the residues on the husks diminished faster. The level of residue on both plant parts varied directly with the quantity of insecticide applied. After 16 days of weathering only 0.42 ppm of the insecticide remained on the stalks and leaves, and 0.02 ppm on the ear husks in plots treated with the 2-pound rate. No detectable residues were found in the ears after 16 days weathering in the field.

6. Residues on Greenhouse Vegetables. Analysis by chemists in Maryland showed 9.9 ppm malathion on greenhouse lettuce 10 days after spraying with $1\frac{1}{4}$ pounds of malathion per 100 gallons of spray. After 14 days the residues had decreased to 2.6 ppm. On similarly treated cucumbers the residue of malathion was less than 1 ppm 2 hours after spraying.

On greenhouse tomatoes a residue of 0.7 ppm was found 3 and 7 days after spraying with 1 pound of tetradifon per 100 gallons of spray. No excess residues were found after spraying the tomatoes with 2 pounds of Kelthane per 100 gallons.

D. Biological Control

1. Sweet Corn Insects. At Tifton, Ga., the nuclear polyhedrosis virus of the corn earworm was used in an early season field trial on sweet corn in which the virus alone and in combination with DDT was compared with a DDT standard and an untreated control. The best control was obtained with a combination of virus and DDT applied at the early-tassel treatment and at 3-day intervals during silking. There was no significant difference between

(1) DDT alone applied in the tassel stage followed by treatments at 3-day intervals in the silking stage, (2) the virus alone applied in the tassel stage followed by treatments at 3-day intervals during silking, or (3) a single virus treatment applied during the tassel stage. All were significantly better than the untreated control.

2. Sweetpotato Insects. In South Carolina the nematode DD-136-bacterium complex caused 59% mortality of the southern potato wireworm within 7 days in soil cages. A spore suspension of the sporozoan, Mattesia grandis, was not effective against the banded cucumber beetle.

3. Cabbage Insects. In further field studies in South Carolina, weekly applications during the fall of 1964 of a commercial Bacillus thuringiensis wettable powder reduced to 13% the proportion of cabbage damaged by the cabbage looper compared to 56% damage to untreated plants. Addition of mevinphos to this pathogen was of no significant value. The B. thuringiensis was essentially as effective as mevinphos, endosulfan, or parathion but none of these materials, as used, gave adequate protection against the cabbage looper. The powder formulation of the pathogen was more effective than a commercial liquid formulation. In other field tests polyhedrosis virus at 1,000 billion polyhedra per acre or 1.2 lb/acre of a commercial B. thuringiensis powder, or both, applied 3 times to heading spring cabbage allowed 25.6 to 90% of the plants to become damaged by the cabbage looper. A suspension of a nuclear polyhedrosis virus stored for 10 months at room temperature was ineffective against third-instar cabbage loopers. Portions of this suspension kept refrigerated (at about 40° F.) or frozen were highly infectious.

In California single applications of cabbage looper nuclear polyhedrosis virus suspensions at 1, 2, or 4 hundred billion polyhedra per acre, or sprays of 0.5, 1, or 2 pounds per acre of B. thuringiensis containing 2.5×10^{10} spores per gram were not sufficient to give adequate protection during the season. Weekly applications of virus suspensions containing 2 or 4 hundred billion polyhedra per acre resulted in an average of 73-74% reduction of cabbage looper larvae after the second application. Similar larval reductions after weekly applications of B. thuringiensis spray at 2 pounds per acre did not occur until after the third weekly application when it gave good control.

In California 53 pathogens were evaluated for effectiveness against corn earworm larvae in laboratory tests. Mortalities of corn earworm larvae within 4 days after treatment ranged from 80 to 100%. The source of these pathogens was the collection of the University of California.

Cabbage looper virus preparations were produced in large amounts for field and basic laboratory studies at Riverside, Calif. Larvae were reared on an artificial diet. Efficient methods of inoculation and harvesting of the virus have been developed.

Tachinid flies, Voria ruralis, were produced in the laboratory at Mesa, Ariz., by exposing half-grown cabbage loopers reared on a defined diet to the flies. Puparia thus produced were accumulated under controlled temperatures of 45 to 50° F. Loopers were introduced into large field cages 12 X 24 X 6 feet and tests were made to determine the effectiveness of introduction of flies or puparia of V. ruralis. Each cage contained 120 lettuce plants; each plant was infested with two first or second instar loopers. Introduction of 24 pairs of flies produced 75% parasitism; introduction of 20 puparia produced 57% parasitism.

4. Pea Insects. Aphidius smithi Sharma & Subba Rao, a parasite of the pea aphid, Acyrthosiphon pisum (Harris), imported from India and released in the Pacific Northwest in 1959 and 1960 has become established and consisted of 3% of all parasites reared from aphids collected throughout eastern Washington in 1964. This parasite also survived the severe winter of 1964-65. It is more prolific than either of two native parasites. Hot, dry weather in the major alfalfa and pea production districts of eastern Washington during July and August of each year reduces the population of the pea aphid, Acyrthosiphon pisum (Harris), to extremely low population densities. Several large cages were transported to a small alfalfa field at the 2,500-foot elevation in the Cascade Mountains for pea aphid parasite production in late June 1964. Approximately 270,000 parasites, chiefly Aphidius pulcher Baker, were produced and later transported to alfalfa fields near Walla Walla, Wash., in September after the pea aphid had started propagating again. Based on the relatively high ratio of parasites to aphids in alfalfa fields in the spring of 1965, this operation was of considerable importance in control of the aphid on peas.

A 9-month survey of seed and forage alfalfa fields at Walla Walla, Wash., in 1964 showed that whereas the pea aphid, Acyrthosiphon pisum (Harris), averaged over 7,000 per 100 sweeps on February 2, from 1,100 to over 6,000 through March, and populations increased to a seasonal peak of 70,000 in forage fields April 16, their numbers declined rapidly thereafter and became rather scarce through October. Parasites and several kinds of predators increased slowly and some species were rarely found until June. Coccinellids were present by mid-March, aphid parasites, lacewings, spiders, syrphids, anthocorids, and geocorids appeared early in April. Populations of adult aphid parasites increased erratically through April, May, and June and were most numerous in late August, September, and October. Several kinds of predators also were most abundant late in the season after the aphid population had declined sharply.

5. Beet Leafhopper. Increasing evidence was obtained that it is practical to control this lone vector of the destructive curly top disease in the whole of southeast Idaho by use of crested wheatgrass and controlled range management. During the spring of 1965 the movement of the leafhopper from desert breeding areas to cultivated areas was one of the lowest on record. Only 10 to 20 leafhoppers were found per 100 feet of sugarbeet row. This low population of the leafhopper is attributed to the planting of much of

the acreage of its key host plant, Russian-thistle, to crested wheatgrass followed by controlled grazing. This project, initiated in 1959 in cooperation with the Bureau of Land Management, Department of the Interior, to replace 300,000 acres of Russian-thistle with permanent range grass, is showing rapid progress. An excellent stand of crested wheatgrass is well established on more than 100,000 acres of the more important breeding areas of the insect.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Banded Cucumber Beetle. Studies in South Carolina of the sex attractant of this cucumber beetle were expanded in cooperation with ARS chemists at Beltsville, Md. Twenty-one synthetic compounds and 68 chromatographic fractions of the natural female lure were bioassayed as male attractants. Several of these proved quite effective. Extracts of the abdomens of at least 32,372 virgin females of banded cucumber beetle adults were sent to Beltsville, Md., for fractionation. Sticky-board traps baited with the natural female lure caught approximately 87% of the males in a one-fourth acre field plot of tomatoes within 30 hours. Some substance in the flowers of plants, probably pollen, seems to be needed for females of spotted cucumber beetles to produce a male attractant. Male banded cucumber beetles did not respond to extracts of spotted cucumber beetle.

2. Sterilization of Banded Cucumber Beetle. In laboratory studies in South Carolina metepa-fed female adults of the banded cucumber beetle laid significantly fewer eggs than untreated ones. Apholate, metepa, and tepa fed to male adults gave significant but varying degrees of sterility. Fresh residues of 0.25% and 4% apholate on glass were highly effective; 1- and 4-day-old residues were only partially effective. No appreciable mortality was noted when males were exposed 1 to 60 minutes to dried 4% apholate residues on glass. Residues of 4% apholate on plastic were highly effective, but very toxic to the insects; those of 2% apholate were only partially effective. A dried residue of 8% apholate on glass was highly effective in sterilization of males.

3. Sterilization of the Cabbage Looper. In California the treatment of cabbage looper pupae with acetone or water solutions containing various concentrations of tepa up to 4% induced a high degree of sterility in male moths. Female pupae were less susceptible to the treatment and concentrations up to 12% in water or 50% acetone did not result in over 55% reduction in the number of viable eggs produced by mated females. Male cabbage looper moths fed .5 or 1% tepa in 10% sugar solutions mated less, longevity was reduced, and the number of copulatory aberrations increased. Males sprayed with .5% aqueous tepa solutions lived as long and mated as frequently as untreated males. Tepa fed moths did not respond to female pheromone extracts in bioassay tests in the same degree as untreated males. The responses of tepa-sprayed males were comparable to those of untreated males. A male cabbage looper moth sterilized with tepa is capable of mating with and transferring sperm with dominant lethals to at least 4 females. The testes

of mated or unmated male moths treated with 1 or 2% tepa showed a slight decrease in size which became more evident as the interval after treatment increased. Unmated tepa treated females deposited few eggs and dissections at various times after treatment showed the presence of variable numbers of fully developed eggs in the ovarioles of both treated and untreated groups. However, in mated females, the numbers of eggs per ovariole decreased as the time after the treatment increased. This indicates that the development of the ova at the time of treatment is an important factor in determining the effects of the chemosterilant treatment on the reproductive tissues of the females. Apparently a number of eggs in the ovarioles of females less than 1 day old, though not mature, are advanced enough in development so that irrespective of chemosterilant treatment, these continue to form the chorion and are laid by the treated female. Once these eggs are laid, eggs in the earlier stages of development at the time of treatment are prevented from further development. Sterile males or sterile females confined in cages with untreated male and female moth populations reduced the reproductive potential of the untreated population. At ratios of 10:1:1, sterile males or females to normal males and females, respectively, the reduction in numbers of larvae produced was over 90% as compared to check treatments. The effect of sterile males and sterile females was additive in this respect.

4. Drosophila Sterilization. In Maryland a high degree of sterilization of drosophila flies in tomato field plots was accomplished by distributing 2% apholate or 3% ENT 50905 in baits on coarse vermiculite or oasis cubes, or in protected glass jars. Eggs laid by females collected from the experimental plots yielded 50% fewer progeny than eggs laid by females collected from untreated tomatoes 1.5 miles distant from the experimental field. Of females collected from apholate-treated plots, a maximum of 81% were sterile. Differences between treatments in these experiments were reduced by extensive interplot movement of flies over 50-foot interplot spacing which was shown by high sterility of female flies collected from untreated check plots.

In laboratory studies at Beltsville, normal male drosophila flies showed no mating preference between untreated females and females sterilized by exposure to 16 kr of cobalt-60 radiation. In other experiments the introduction of irradiated (16 kr) male drosophila flies into a population of untreated flies suppressed the reproductive potential more than did the introduction of a like number of sterilized female flies. The same degree of sterility was attained when only sterilized males were introduced into the population as when the same number of sterilized males with associated sterile females were introduced. According to these studies no increase in efficiency of a sterile male release program would result by sexing Drosophila melanogaster to remove the majority of females from treated males before release.

Of 55 samples screened as baits for drosophila flies at Beltsville in 1964, none approached the attractiveness of the so-called Beltsville standard bait containing 10% granulated sugar, 4% dry yeast, and 1% cider vinegar, in water. However, addition of 5% glycerin doubled the attractiveness of this bait, probably because of the hygroscopic qualities of glycerin that slowed the

drying out of the original bait and the loss of attractiveness. ENT 50905 at 1% concentration in the standard sugar-yeast-water bait gave high sterility of male drosophila adults for about 2 weeks. Some males showed considerable rejuvenation after this period whereas apholate-treated flies remained sterile for life.

5. Aluminum Mulch for Aphid Control. In experiments at Deerfield Beach, Fla., conducted by Beltsville, Md., and Farmingdale, N.Y., laboratories in cooperation with Florida Agricultural Experiment Station, soil mulch of reflective aluminum foil and black plastic on plots of straight-neck bush squash, planted January 15, aphid-transmitted watermelon mosaic virus infection appeared earlier in unmulched check plots. Aphids flying into the plots were reduced 90% by the aluminum mulch and 29% by the black plastic. At the end of March, 4 weeks after beginning of harvest, 68.5% of check plants were virus infected compared to 51 and 4.1% in black plastic and aluminum mulches, respectively. Although virus infection increased rapidly in April, late infected aluminum-mulched plots produced marketable fruits. In continuing experiments at Beltsville in the spring of 1965 on summer squash, reductions of 75 and 37.5%, respectively, of aphid-transmitted virus infections resulted in plots mulched with aluminum and black plastic, when compared with unmulched check plots.

6. Sweet Corn Insects. At Tifton, Ga., testing of ether extracts from the virgin fall armyworm, Spodoptera frugiperda, corn earworm, Heliothis zea, and true armyworm, Pseudaletia unipuncta, moths has shown that a specific mating stimulant (sex pheromone) is produced by the female of each species. In all three insects the lure was found within the last two abdominal segments. Attempts to recover the pheromone from heads, thoraces, and/or upper abdominal segments have failed. When male fall armyworm moths, 3 to 6 days old, were exposed to 0.2 equivalent of females of different ages, only 2% of the males reacted to extracts of females 12 hours old, 32% reacted to extracts of females 24 hours old, 80% to females 36 hours old, and 98% to females 48 hours old. When 3- to 6-day-old males were exposed to varying concentrations of extracts on 3-day-old females, 98% of the males reacted to 0.02 female moth equivalent (FME), 88% reacted to 0.002 FME, 66% reacted to 0.0002 FME, and 20% reacted to 0.00002 FME.

F. Evaluation of Equipment for Insect Detection and Control

1. Suction Fan in Light Traps. In field studies in South Carolina a suction fan in a 15-watt blacklight trap tended to reduce the catch of adults of southern potato wireworm and increase that of adults of corn earworm, cabbage looper, and 2 species each of armyworms and of cutworms.

2. Insects Attacking Sweet Corn. At Tifton, Ga., agricultural engineers worked with entomologists and pesticide residue chemists to develop a high clearance tractor-mounted revolving brush applicator to treat corn silks for corn earworm control. Applications at the rate of 1.3 pound per acre produced two to four times more insecticide residue on ear tips than emulsion

sprays applied at the rate of two pounds per acre. The brush applications resulted in as good earworm control as that obtained with emulsion sprays.

3. Applicator for Low Volume Sprays on Small Plots. In field tests in Maryland, progress was made in the development of a simple sled-type unit for applying ultra low volume sprays to small plots of row crops. The undiluted liquid insecticide is discharged from a paint sprayer or mixtures with Freon are discharged from pressurized containers. A plastic hood confined the insecticide particles around the plants.

4. Spray Deposit Pattern of ARS Bell 47 D-1 Heliocopter. The spray deposit pattern curves for tests conducted by entomologists and agricultural engineers in Oregon using a symmetrical arrangement of spray nozzles with either D8-56 or D6-46 orifices on a 26-foot boom mounted both in the forward and amidship positions moving at 30, 45, and 60 mph gave the following information: (1) At the 5-8 foot flight elevation: (a) The swath widths measured at the mean deposit rate level were all approximately 40 feet; (b) all pattern curves showed a zone of low deposit located from 4 to 10 feet right of center and second low deposit zone was 5 feet left of center--the general shape of the curve was pyramidal. (2) At the 20-25 foot flight elevation: (a) The application swath was approximately 5 feet wider than for the lower flights; (b) the overall shape of the patterns was the same as for the lower flight levels; and (c) height of flight made no appreciable difference in pattern shape due to boom location or speed of application.

The pattern studies for tests conducted with a 48-foot boom mounted both in the forward and amidship positions showed that: (1) At all flight levels the swath widths were increased by an amount equivalent to the increased boom length; (2) speed and boom location had no bearing on swath width; (3) the location of the low deposit zones was approximately the same as for the shorter boom; (4) the deposit curves for the 20-25 foot application height were more trapezoidal in shape; and (5) the most reasonably uniform deposit pattern curve was obtained with the forward mounted boom, a 60 mph application speed and the 20-25 foot application height.

In studies of spray coverage on pole beans from applications with the spray boom mounted on the front ends of the skids and carrying 27 symmetrically-spaced nozzles, the mean recovery rate of spray deposited on Mylar tape at the 6-foot level was 2.78 gpa on the upper leaf surfaces and 0.44 gpa on the under leaf surfaces. Similar results were obtained at the 4-foot and 2-foot levels. The spray deposits on the upper leaf surfaces at the $\frac{1}{2}$-foot level averaged 51% of those recorded at the 6-foot level, while under leaf deposits at the $\frac{1}{2}$-, 2-, 4-, and 6-foot levels ranged from 15 to 16% of that at the upper leaf surfaces.

The Bell 47 D-1 was used to determine the effects of spray coverage penetration when applications were made to corn at high (57 mph) and low (30 mph) speeds at 3 to 5 feet above the plant canopy. Analysis of the spray deposits showed that the gallonage rates on the upper leaf surfaces from applications

at 30 mph were approximately twice the rates recorded at 57 mph. At the higher discharge rate and slower speed, the under leaf surface deposits were about the same for the 2 speeds with the exception of that at the ½-foot level where 67% more spray was recovered from application at the slower speed.

5. Marking of Forest Trees for Spray Operations. A portable unit for marking forest tree tops was developed in Oregon in cooperation with the Forest Service. It consisted of an air pressure and paint supply tank mounted on the side of the ARS Bell 47 D-1 helicopter. A hose line, controlled by a valve, led to a ½-inch I.D. boom, 8 feet in length, mounted on a bracket at the forward tips of the landing skids. This boom extended outward in front of the pilot with a tee section about 2 feet long on the end with 3 Spraying Systems Co. diaphragm nozzles. Orange latex marking paint was used in the tank and pressurized with air to 100 pounds. The marking was accomplished by flying to the desired tree top, momentarily hovering over the tree, and spraying about one pint of the bright orange paint on the tree top. The helicopter must be capable of hovering at density altitude for use of this method.

6. Aerial Spray Drift. In Oregon, preliminary studies on spray drift from the ARS Rawdon T-1-250 low-wing monoplane showed that spray trapped in the wingtip vortices was drawn through the air after the spray boom had been shut off at the end of a spray run. More spray was carried farther in a straight flight after cut-off than when the spray cut-off occurred before pull-up. The chance of spray entrainment was enhanced when the spray was cut off during pull-up. Measurable amounts of spray were recovered on the ground for 500 feet past the cut-off line.

G. Varietal Evaluation for Insect Control

1. Sweetpotato. In continued laboratory and field studies in South Carolina, Louisiana breeding line L3-64 again proved outstanding in resistance to soil insect attack, receiving little or no economic damage under conditions where several leading commercial varieties would have had to be drastically culled to be marketable. L3-64 was resistant to injury by the southern potato wireworm, sweetpotato flea beetle larvae, a white grub, and a Diabrotica-Systena species complex. Other breeding lines under study showed significant degree of resistance to one or more of the insect species and some were especially susceptible to certain species. None of the varietal characteristics considered were found to be clearly associated with resistance to the insects involved. Attempts to develop a laboratory technique for screening a large number of sweetpotato breeding lines or varieties for their degree of resistance to soil insect injury were only partially successful.

Field-plot evaluations of 64 varieties or breeding lines in Louisiana indicated considerable differences in their susceptibility to insect attack. An attempt to develop a method of screening candidate lines for insect resistance in greenhouse benches yielded promising results.

2. Cabbage. Exploratory field studies in South Carolina indicated that significant resistance to cabbage looper injury existed among 13 breeding lines and several commercial varieties of cabbage. No differences in rate of development of the larvae on a green and a red variety of cabbage were apparent.

3. Sweet Corn. Preliminary field tests in 1964 at Tifton, Ga., indicated that the planting dates of sweet corn influenced the amount of corn earworm damage with either natural or artificial infestations. Generally, there was less damage with good growth conditions. Since the lack of an adequate earworm infestation can give a false indication of resistance, natural infestations were not as reliable as artificial infestations.

Field cage studies showed that fewer earworm larvae could establish on unpollinated silks than on pollinated silks, indicating that either pollen itself or the physiological or physical changes in silks initiated by fertilization helped larvae to become established.

Although slitting the husk of a resistant sweet corn inbred increased earworm damage, some factor or factors other than husk tightness contribute to resistance. Injury was not as great in resistant lines with slit husks as in susceptible inbreds with slit husks.

Six Southern Grain Insects Research Laboratory inbreds have indicated good resistance and quality in a hybrid testing program. Backcrosses of the inbreds in Walter's White have shown increased inbred vigor and maturation, yet little of the earworm resistance or quality has been sacrificed.

At Lafayette, Ind., 26 sweet corn inbreds, 51 experimental sweet corn hybrids, and 6 commercial sweet corn hybrids were grown and evaluated for earworm resistance. In general, it was found that longer husk extensions were associated with less earworm injury, although not in every case. Relatively short husk extensions were not always associated with susceptibility to the earworm. Twenty-seven of the experimental hybrids were more resistant than the most resistant commercial hybrid.

H. Insect Vectors of Diseases.

1. Bean Insects. In 9 series of trials at Yakima and Prosser, Wash., 15 to 30 viruliferous six-spotted leafhoppers, Macrosteles fascifrons, were placed on each of 218 bean plants and allowed to feed for 7 to 21 days. This attempt to transmit a Washington strain aster yellows from Erigeron canadensis to Red Mexican beans failed.

In Washington a study of possible virus vectors on beans showed the intermountain leafhopper to be the most abundant followed in order by the six-spotted leafhopper and the beet leafhopper. Eleven species of leafhoppers were found on beans and 13 on nearby clover. Nine species of aphid were

found on beans, 8 of which were collected only in the winged form. The pea aphid, the English grain aphid, and the green peach aphid were the most abundant.

2. Sweet Corn Insects. Cooperative research by State and Federal entomologists and pathologists have shown that the disease infecting corn in the South and Midwest since 1962 is due to two separate viruses. The one in the South is a persistent leafhopper-transmitted virus known as corn stunt while the one in the northern area is a non-persistent virus, now named maize dwarf mosaic, which can be transmitted by aphids and also mechanically. There is evidence that the two diseases may overlap in Missouri and Arkansas.

Cooperative research by State and Federal workers at Wooster, Ohio, established that the corn leaf aphid can transmit maize dwarf mosaic.

At Tifton, Ga., Dalbulus maidis, a known vector of corn stunt disease, was collected on volunteer corn from August 25 until the first killing frost on November 15, 1964.

Under greenhouse conditions at Tifton, 138 transmission tests were attempted using leafhoppers, other than D. maidis collected from corn growing in fields with plants displaying symptoms of corn stunt disease. Eighteen genera and 22 species of leafhoppers were represented. No symptoms of corn stunt disease were observed in any test.

In Mississippi 33 species of leafhoppers were collected on corn during the 1964 growing season. D. maidis was collected in large numbers during the period August 18 to November 19 in Louisiana, Texas, and Mississippi. Corn stunt virus transmission trials were conducted with 8 common species of indigenous leafhoppers. Discolorations which were not typical corn stunt virus symptoms developed on corn following feeding trials with Graminella nigrifrons, but no positive symptoms of corn stunt were observed.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Callahan, P. S. 1964. An inexpensive actinometer for continuous field recording of moonlight, daylight, or low intensity evening light. J. Econ. Entomol. 57: 758-60.

Callahan, P. S. 1964. Basic semiconductor circuitry for ecological and behavioral studies of insects. USDA, ARS 33-94, 15 pp.

Callahan, P. S. 1965. A photoelectric-photographic analysis of flight behavior in the corn earworm, Heliothis zea, and other moths. Ann. Entomol. Soc. Amer. 58: 159-69.

Callahan, P. S. 1965. Far infra-red emission and detection by night-flying moths. Nature 206(4989): 1172.

Cuthbert, Frank P., Jr., and W. J. Reid, Jr. 1965. Four little-known pests of sweetpotato roots. J. Econ. Entomol. 58: 581-3.

Henneberry, T. J., W. L. McGovern, A. H. Yoemans, and H. C. Mason. 1964. Sexing large numbers of Drosophila melanogaster adults by a size differential. J. Econ. Entomol. 57: 769-70.
Henneberry, T. J., and D. Shriver. 1964. Two-spotted spider mite feeding in bean leaf tissue of plants supplied various levels of nitrogen. J. Econ. Entomol. 57: 377-9.
Henneberry, T. J. 1964. Effect of host plant nutrition on susceptibility to malathion of two strains of two-spotted spider mites. J. Econ. Entomol. 57: 674-6.
Starks, K. J., W. W. McMillian, A. A. Sekul, and H C Cox. 1965. Corn earworm larval feeding response to corn silk and kernel extracts. Ann. Entomol. Soc. Amer. 58: 74-6.
Vail, Patrick V. 1965. Colonization of Hypogastrura manubrialis (Collembola: Poduridae) with notes on its biology. Ann. Entomol. Soc. Amer. 58: 555-61.

Insecticidal and Cultural Control

Cox, H C, and M. C. Bowman. 1965. Uptake of fall armyworm larvae exposed to residues. J. Econ. Entomol. 58: 87-92.
Henneberry, T. J., and W. R. Smith. 1965. Malathion synergism against organo-phosphate resistant two-spotted spider mites. J. Econ. Entomol. 58: 312-4.
Stone, M. W. 1965. Biology and control of the lima bean pod borer in southern California. USDA Tech. Bull. 1321, 46 pp.

Insecticide Residue Determination

Butler, Lillian I., Donald A. George, Harold W. Rusk, and Jay C. Maitlen. 1965. Insecticide residues on and in tomatoes. USDA, ARS 33-101, 11 pp.
Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. Field evaluation of an electrostatic duster. J. Econ. Entomol. 58: 71-4.
Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. DDT residues on sweet corn ear tips and silks after treatment with dust, spray, or granular formulations. J. Econ. Entomol. 58: 55-8.

Biological Control

Elmore, John C., and A. F. Howland. 1964. Natural versus artificial dissemination of nuclear polyhedrosis virus by contaminated adult cabbage loopers. J. Insect Path. 6: 430-8.

Insect Sterility, Attractants, and Other New Approaches to Control

Henneberry, T. J., F. F. Smith, and W. L. McGovern. 1964. Some effects of gamma radiation and a chemosterilant on the Mexican bean beetle. J. Econ. Entomol. 57: 813-5.

Smith, Floyd F. 1965. Chemosterilant treatment of two greenhouse spider mites. Proc. 12th Internat'l. Cong. Entomol., London. July 8-16, 1964. (Abstract)
Smith, Floyd F., A. L. Boswell, and T. J. Henneberry. 1965. Chemosterilant treatment of two greenhouse spider mites. J. Econ. Entomol. 38: 98-103.

Evaluation of Equipment for Insect Detection and Control

Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. Field evaluation of an electrostatic duster. J. Econ. Entomol. 58: 71-4.
Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. DDT residues on sweet corn ear tips and silks after treatment with dust, spray, or granular formulations. J. Econ. Entomol. 58: 55-8.
Young, V. D., R. G. Winterfeld, C. E. Deonier, and C. W. Getzendaner. 1965. Spray-distribution patterns from low level applications with a high-wing monoplane. Agr. Avia. Internat'l. Agr. Avia. Centre, the Hague, Netherlands, 7(1): 18-24. Also, USDA, ARS 42-99, 8 pp.

Varietal Evaluation for Insect Resistance

Knapp, J. L., P. A. Hedin, and W. A. Douglas. 1965. Amino acids and reducing sugars in silks of corn resistant or susceptible to corn earworm. Ann. Entomol. Soc. Amer. 58: 401-2.

Insect Vectors of Diseases

Stoner, Warren N. 1964. Corn stunt and the leafhoppers Dalbulus maidis (DeL. & W.) and Dalbulus elimatus (Ball.). Proc. No. Cent. Br. Entomol. Soc. Amer. 19: 99. (Abstract)
Stoner, Warren N. 1964. Corn stunt disease in the United States through 1963. USDA, Plt. Dis. Rptr. 48: 640-4.
Stoner, Warren N., and A. J. Ullstrup. 1964. Corn stunt disease. Miss. State Univ., Agr. Expt. Sta. Inf. Sheet 844, 4 pp.
Stoner, Warren N., Lansing E. Williams, and Leonard J. Alexander. 1964. Transmission of the corn leaf aphid, Rhopalosiphum maidis (Fitch) of a virus infecting corn in Ohio. Ohio Agr. Expt. Sta. Res. Circ. 136, 3 pp.
Stoner, Warren N. 1965. A review of corn stunt disease (Achaparramiento) and its insect vectors, with resumes of other virus diseases of maize. USDA, ARS 33-99, 35 pp.

AREA NO. 2. POTATO INSECTS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes demanded by the consumer. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the ecology and biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Growing concern over problems associated with insecticides which may also include adverse effects from residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, makes it imperative that an increasingly strong research effort be directed to the development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

USDA AND COOPERATIVE PROGRAM

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono, Me., Beltsville, Md., and Charleston, S. C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry. In cooperation with the Crops Research Division studies on plant resistance were initiated at Ames, Iowa, under a grant to the Iowa State University of Science and Technology. Biological control studies at the University of Maine were initiated under a cooperative agreement.

The Federal scientific effort devoted to research in this area totals 4.4 professional man-years. Of this number 0.7 is devoted to basic biology; 1.5 to insecticidal and cultural control; 0.6 to insecticide residue determination; 0.6 to biological control; 0.2 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for control and detection; 0.2 to insects that spread potato diseases; and 0.3 to program leadership.

In addition Federal support of research in this area under grants and cooperative agreements totals 1.2 man-years. Of this total 0.7 is devoted to biological control and 0.5 to plant resistance to insects.

A P.L. 480 Project in India on transmission of potato diseases by the green peach aphid was developed.

PROGRAM OF STATE EXPERIMENT STATIONS

The State experiment stations have an effective potato insect research program under way.

The evaluation and integration of newly-developed chemicals with currently used insecticides, cultural methods, and pathogenic agents is being carried out. Information is being obtained on the influence of pesticide treatment on the development of natural enemy populations. Analyses of both tubers and soil are being performed to determine the amount of insecticide residue present following treatment and the rate of decomposition.

Studies are in progress to establish the relationship between insect-transmitted potato diseases and their vectors. The factors influencing these basic relationships are being analyzed and promising leads obtained are evaluated for their use in control.

Varietal crosses, selected seedlings, foreign varieties, Solanum species and interspecific hybrids are being evaluated for insect resistance. Resistant and susceptible strains are being studied to determine the nature of resistance mechanisms.

A total of 10.8 professional man years is devoted to potato insect research in the States.

PROGRESS - USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

1. Aphids. Viviparous, summer forms of the green peach aphid, frequently overwinter in the Pacific Northwest on various winter-hardy plants in protected ecological niches. During the early spring of 1964 they were found overwintering at many locations in eastern Washington, northeastern Oregon and southeastern Idaho on shepherds-purse (Capsella bursa-pastoris), flixweed tansymustard (Sisymbrium sophia), running mallow (Malva rotundifolia), bouncing-bet (Saponaria officinalis), clasping-pepperweed (Lepidium perfoliatum) and tumblemustard (Sisymbrium altissimum). Following the severe winter of 1964-65 overwintering of the summer forms occurred at fewer locations and on fewer host plants but included hedge glorybind (Convolvulus sepium) not previously recognized as an overwintering host.

During winters in Washington when the green peach aphid is able to overwinter in both the egg and summer form stages, winged migrant forms are always produced earlier in the spring by the anholocyclic, or summer-form, than by the holocyclic form that overwinters in the egg stage. It was also found that whereas stone-fruit trees on which the holocyclic form lays its

eggs in the fall is not an overwintering reservoir for potato virus diseases, cull or stored potatoes used partly or wholly for overwintering some individuals of the holocyclic line may serve as an overwintering reservoir for some potato virus diseases.

Potato-infesting aphids were never abundant on potatoes at Presque Isle, Maine, in 1964. Fall and spring surveys indicated that the buckthorn aphid and the foxglove aphid would not be abundant but that the green peach aphid would be more abundant than usual, and the potato aphid of average abundance. Of several natural control factors, entomogenous fungi seemed most important. The action of predators on the primary host of the buckthorn aphid the preceding fall also was a strong contributory factor.

2. The Garden Symphylan. This pest severely damaged Russet Burbank potatoes in a field near Yakima, Wash., in 1964. Damage was spotty with some loads having as high as 35% culls. No damage occurred to the Norland variety planted in the same field.

3. The Six-Spotted Leafhopper. A 3-year study on the abundance of this insect on various host plants from May to September in Washington showed host preferences in the following order: Clover, carrots, winter wheat, fall barley, and potatoes. Maximum populations of adults were found in clover in July, carrots in August, winter wheat in July, fall barley in June, and potatoes in August.

4. Southern Potato Wireworm. At Charleston, S. C., 98% of the wireworm adults caught in light traps were of this species. A sample of 62 females examined in May and early June revealed that only 14% contained spermatophores indicating a very low percentage had mated. In cultivated land 141 adults were caught per trap per night in comparison with 0.08 per trap per night 100 feet within woodlands from May 28 to June 21. Wireworms taken from 19 fields were 93% southern potato wireworms.

B. Insecticidal and Cultural Control

1. Aphids. In field experiments in Washington five aphicides registered for use against the green peach aphid were applied as sprays to foliage with ground equipment. Satisfactory control was obtained with endosulfan 16 oz., endrin 9 oz., and demeton 8 oz. per acre but not with parathion 12 oz., or diazinon 8 oz. Di-Syston was the most effective material applied in sidedress applications of granules or concentrated water emulsions. Phorate and dimethoate were much less effective.

Following the mild winter of 1963-64, winged spring migrant forms of the green peach aphid were produced on both herbaceous and woody overwintering host plants throughout the potato growing area of eastern Washington. A survey of 30 commercial fields of Russet Burbank potatoes made in August and September showed that 5 applications of endosulfan kept the aphid at levels required to prevent damage from leaf roll carried by the insects.

In 4 fields receiving this treatment an average of only 2% of the harvested tubers contained net necrosis, an internal defect caused by the disease. Non-treated fields contained as much as 33% net necrosis.

In field experiments in Maine, foliage application of endrin, endosulfan, or phosphamidon and soil applications of Di-Syston in the seed furrow at planting time continued to give good control of aphids. The potato aphid continued to be more difficult to control than the green peach aphid, the buckthorn aphid, and the foxglove aphid. DDT applied weekly as a foliar spray was not only ineffective against these aphids but appeared to reduce the abundance of predators and parasites and thereby to increase the aphid populations. The use of insecticides in experimental plots did not affect total yield of Katahdin or Chippewa potatoes but tended to reduce the size of the tubers, especially in the Katahdin variety. Leaf roll readings made in 1964 of plants from tubers produced in 1963 showed the spread of leaf roll to be 6 to 25 times greater in untreated plots than in the treated. Little or no spread occurred in plantings treated with Di-Syston. In untreated plantings, the spread of leaf roll in Russet Burbanks was 1 to 4 times more than in Katahdins.

2. Spider Mites. A single application of 1 pound of phorate per acre in a spray was the most effective of 13 materials tested in Washington for control of the two-spotted spider mite on potatoes.

3. Wireworms. In field experiments in Washington, phorate was much superior to diazinon for control of the sugarbeet wireworm when applied as granules broadcast on the soil surface and worked into the soil before planting. Phorate, however, may leave residues in the tubers. Since there is no tolerance for this material in potatoes, this use cannot be recommended. In similar experiments, parathion was more effective than diazinon for control of the Great Basin wireworm, Ctenicera pruinina. Preliminary evaluations of several granular formulations of parathion showed that it is possible to stabilize, or hold, the insecticide so tightly in the granules that wireworms are killed too slowly, although some mortality occurs much later than would normally be expected.

The soil fumigant, 1,2-dibromo-3-chloropropane did not give satisfactory control of wireworms when applied as sidedress applications to potatoes at 4 pounds per acre.

C. Insecticide Residue Determinations

1. Chlordane Penetration into Potato Pulp. In cooperative experiments at Presque Isle, Maine, with the Velsicol Corporation, it was revealed that although residues were much below tolerance, chlordane apparently penetrates and is deposited in cell walls of the potato tuber. From 0.09 to 0.12 ppm of chlordane was found in potato pulp, the residue of cell walls after the cells are crushed and the starch grains have been washed out with water in the starch-making process. From 0.09 to 0.11 ppm of chlordane were found

in Katahdin potato tubers grown in 1964 in soil treated at planting with chlordane at 4 to 8 lb/acre.

2. Organic Chlorine Insecticides. Chemical analysis in 1964 of Maine grown potato tubers showed that residues of insecticide were below the tolerance in tubers of Katahdin or Chippewa potatoes at harvest from plants growing in soil treated at planting with DDT at 10, aldrin at 2 or 4, chlordane at 4 or 8, or endrin at 1 pounds per acre. Also there were no measurable residues of endrin found in tubers from plants treated with two foliar sprays at 1/2 lb/acre.

In Washington the registered rate of 10 pounds of chlordane per acre applied broadcast and disked in the soil before planting potatoes in a field of sandy loam soil and a field of silt loam soil did not result in above-tolerance levels of residues in Russet Burbank potatoes but 20-pound rates resulted in nearly twice the established tolerance.

Samples of potatoes grown at Beltsville, Md., in soil treated with 10 pounds of DDT per acre and up to 8 pounds of chlordane per acre were analyzed for chlorinated hydrocarbon residues. The DDT and chlordane residues found were below the established tolerances of 1 and 0.3 ppm, respectively.

3. Organophosphorus Insecticide Residues in Potatoes. In field experiments in Washington, Di-Syston, schradan, and a mixture of the two were applied as granules in narrow bands at various depths in the soil before planting of potatoes. When Di-Syston was applied at 3 pounds per acre, residues of 0.16 and 0.07 ppm were found in potatoes where the applications were at the 3- to 6-inch and the 9- to 12-inch depths, respectively. No detectable residues were found in potatoes where the Di-Syston was applied at depths of 6 to 9 inches or 12 to 15 inches. Schradan at the same rate applied at all four levels resulted in residues in the potatoes with the larger amounts, 0.21 and 0.24 ppm, being found from the 9- to 12-inch and the 12- to 15-inch applications, respectively. The mixture of 2 pounds of Di-Syston and 1 pound of schradan also gave residues at all levels ranging from 0.21 to 0.48 ppm when calculated as Di-Syston and 0.12 to 0.26 ppm when calculated as schradan. The analytical method used did not distinguish between Di-Syston and schradan. In other experiments, granular and emulsifiable concentrate applications of dimethoate, Di-Syston, phorate, or schradan were made as a side dressing to potatoes a week after planting, either alone or in mixtures at the rate of 2.5 pounds per acre. Only dimethoate alone gave no residues in the harvested potatoes. The maximum residue found was 0.55 ppm calculated as Di-Syston.

Sidedress applications of parathion at 3 pounds per acre after the potato plants were up resulted in significant quantities of parathion residue in the harvested tubers indicating the need for a tolerance before parathion is used in this manner on commercial plantings. Parathion applied broadcast at the same rate and worked into the soil before planting continued to

leave no residues in the tubers.

4. Phorate and Zinophos in Soil. Phorate was applied to plots in Washington by broadcasting as granules at the rate of 3 pounds of active ingredient per acre and Zinophos (O,O-diethyl O-2-pyrazinyl phosphorothioate) at the rate of 2 pounds per acre. Soil samples were analyzed at intervals from zero to 42 days after application of the insecticide. The phorate content was 1.38 ppm immediately after application and 0.21 ppm after 42 days; the corresponding Zinophos residues were 0.82 and less than 0.08 ppm.

D. Biological Control

Aphids. The number of aphid predators were greatly decreased in potato plantings at Presque Isle, Maine, in 1964, by spraying weekly with DDT. Two species of parasites, Trioxys carolinensis Smith and Aphelinus mali (Haldeman), not hitherto recorded from potato-infesting species of aphids in Maine, were reared from field-collected aphids.

General biology studies of a coccinellid aphid predator, Coccinella septempunctata, recently introduced from France, were begun at Presque Isle, Maine, in 1964. There is a possibility it can become established since, under identical conditions of hibernation in outdoor cages, it survived the winter as successfully as did the two most common species of ladybird beetles occurring locally. In another study, a very light dosage of the insecticide carbaryl proved highly toxic to the beetle. Affected beetles not killed outright by brief contact exposure on treated pepper foliage apparently never fully recovered. Egg deposition was greatly reduced following the required long period of recovery.

Important advances were made in techniques for rearing C. septempunctata utilizing closed glass or plastic jars containing a layer of excelsior to aid the larvae in avoiding each other. Either living aphids or quick-frozen aphids were satisfactory as food for the beetle larvae or adults. However, for the adult beetles the aphid diet was supplemented by feedings of a mixture of water, honey pollen and protein hydrolysate. About 1/2 man day was required to obtain 1,000 2nd instar larvae for release in field plots. One technician should be able to rear 8,000 to 10,000 per week with adequate aphids and equipment.

In small plot field experiments promising results were obtained with the distribution of predators for aphid control. Aphids did not become as abundant in plots in which eggs or larvae of C. septempunctata or eggs of Chrysopa spp. were put on the foliage of potato. Maximum control was 56 percent in these preliminary tests.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Preliminary tests indicated that adult Limonius spp. wireworms in Washington are attracted to yellow and orange objects.

F. Varietal Evaluation for Insect Control

1. Garden Symphylan. Preliminary observations in Washington indicated that this pest does not attack the tubers of the Norland variety of potato. Another red-skinned variety, LaSoda, and the Russet Burbank variety were susceptible to damage.

2. Six-Spotted Leafhopper. Bliss Triumph and Red Pontiac varieties of potato in Washington were less tolerant of the six-spotted leafhopper-transmitted aster yellows disease complex than Russet Burbank variety.

G. Insect Vectors of Diseases

1. Six-Spotted Leafhopper. A 3-year study of this insect as the vector of the mild, Washington strain of aster yellows on potatoes showed the disease to be of much less importance in Washington than leaf roll, transmitted by the green peach aphid. Although aster yellows caused many abnormalities in potato plants, such as yellow, red or purple colored leaves and stems, adventitious - or axillary - production of stems, spurs or aerial tubers and phyllody in the floral parts, the effect of the disease on potato tubers was not of great economic importance to growers of table stock crops. Tubers produced on infected plants either failed to sprout after winter storage, or if sprouting occurred, the sprouts were weak and produced spindling plants. This factor makes aster yellows a serious problem in seed-growing areas. Strangely enough, infected Russet Burbank potatoes remained hard and crisp during storage whereas infected Red Pontiac potatoes dehydrated rapidly, even prior to harvest, and soon became flabby and unsuitable as food. The area within the vascular ring of infected Russet Burbank potatoes was frequently gray in color although this off-color was not particularly objectionable to the consumer.

Although the six-spotted leafhopper overwinters in the egg stage in various grain and grasses the adults do not become abundant until July and August at which time most crops of potatoes are three-quarters grown. Late-season spread of aster yellows in central Washington probably prevents severe damage from this disease.

2. Aphids. A potentially serious virus disease situation in potatoes is developing in northeastern Maine. Leaf roll and potato virus-Y have gradually become more prevalent in seed stocks--especially in Russet Burbanks, the yearly acreages of which are continuing to increase. Since the advent of the use of planting-furrow application of granular systemic insecticides, seed-potato growers increasingly have discontinued the practice of removing the infected plants from their fields. Table-stock growers to not rogue their fields. In recent years the relative composition of the aphid population has gradually changed with an increasing proportion being the green peach aphid--the most important vector of leaf roll and of virus-Y. Systemic insecticides applied at planting time do not keep the potato plants sufficiently free of aphids towards the end of the season to

prevent late-season spread of leaf roll. A continuation of these trends could result in a repetition of the serious leaf roll situation that occurred in the late 1930s and early 1940s.

At Presque Isle, Maine, 49 percent protection from spread of leaf roll was obtained when viruliferous green peach aphids were placed in plots of Chippewa potatoes one week after the second of two weekly foliar applications of a 1/2-percent chlorocholine chloride-water mixture at 125 gallons per acre. This degree of protection is encouraging in view of the fact that the aphids were not removed from the plants prior to harvest some five weeks later. The mode of action of this chemical in preventing infection is not known. Absorption and translocation in the plant seems likely, since some protection from infection was experienced when the potato plants were sprayed with the mixture one week after being infested with the viruliferous aphids.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Insecticidal and Cultural Control

Day, Augustine, F. P. Cuthbert, Jr., and W. J. Reid, Jr. 1964. Control of the southern potato wireworm, Conoderus falli Lane, on early crop potatoes J. Econ. Entomol. 57: 468-70.

Cuthbert, Jr., F. P., W. J. Reid, Jr., and Augustine Day. 1965. The southern potatc wireworm--how to control it on Irish potatoes. USDA Leaflet No. 534.

Shands, W. A., B. J. Landis, and W. J. Reid, Jr. 1965. Controlling potato insects. USDA Farmers' Bulletin No. 2168 (Revised).

Onsager, J. A. 1965. Crop rotation as related to wireworm control in potatoes. Wash. State Potato Comm. Spud Topics 9(19): 1-3.

Landis, B. J., W. A. Shands, and G. W. Simpson. 1965. Hazards of pesticide drift from potato fields. The Potato Assoc. of Amer. The 1965 Potato Handbook 10: 14-30.

Landis, B. J. 1965. Potato insect control. Fourteenth National Potato Util. Conf. Rep. USDA, ARS 74-30, pp. 78-9.

Onsager, J. A. 1965. Wireworm control as affected by soil temperature. Wash. State Potato Comm. Spud Topics 9(17): 1-3.

Onsager, J. A., and B. J. Landis. 1964. Tips on choosing of insecticides and time of applications for wireworm control. Wash. State Potato Comm. Spud Topics 9(11): 1-2.

Landis, B. J., D. M. Powell, and G. T. Hagel. 1965. The 1964 aphid control program in relation to leaf roll spread and development of net necrosis. Wash. State Potato Comm. Spud Topics 9(18): 1-2.

AREA NO. 3. DECIDUOUS FRUIT, TREE NUT, GRAPE AND BERRY INSECTS

Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes, and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural, and other non-chemical methods of control are only partially effective. Consequently, dependence must be placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish, and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical, and safer insecticides; and an urgent need, because of concern over the use of insecticides, for intensified research on alternative types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and materials that affect insect growth and reproduction, including chemosterilants. More research is needed on integrated chemical-biological control programs with emphasis on less intensive insecticide usage, so that the maximum benefits from parasites, predators, and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, to discover the insect and mite vectors of the diseases and to determine their host preferences, distribution, and habits. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division. Work is also being

conducted under grants at the Washington, North Carolina, California, and Colorado Agricultural Experiment Stations, and at Brigham Young University in Utah.

The Federal scientific effort devoted to research in this area totals 21.6 professional man-years. Of this number 4.2 is devoted to basic biology and nutrition; 5.7 to insecticidal control; 2.1 to insecticide residue determinations; 0.5 to biological control; 4.6 to insect sterility, attractants, and other new approaches to control; 0.6 to evaluation of equipment for insect detection and control; 0.1 to varietal evaluation of resistance; 2.6 to insect vectors of plant virus diseases; and 1.2 to program leadership.

In addition Federal support under grants provides for a total of 3.7 professional man-years of research in this area. Of this total 2.1 is devoted to basic biology, physiology, and nutrition and 1.6 to insect sterility and attractants.

Additional research is in progress under grants of PL 480 funds (Projects E21-ENT-2 and 5) to the Institute of Pomology, Skierniewice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites as influenced by acaricides and for studies on the biological control of mites, aphids, and scale insects on deciduous tree fruits and effects of pesticides on natural enemies. Studies were also initiated by the Institute of Pomology, under PL 480 (Project E21-ENT-8) to study the mite fauna in Poland orchards with special reference to the relation between phytophagous and predaceous species. A portion of a grant of PL 480 funds (Project A17-ENT-5) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

PROGRAM OF STATE EXPERIMENT STATIONS

A well rounded research program in this area is in progress in the States. Studies range from virus disease transmission by insects to the development of control measures involving comparisons of new insecticides. Integrated control measures are being developed in which the use of chemicals, cultural methods, natural enemies--in short, all factors which contribute to injurious insect control--are coordinated for maximum effectiveness. Schedules and new methods of application of pesticides are being evaluated to reduce residue levels and slow the development of pest resistance to these chemicals.

New techniques utilizing chemosterilants, repellents, and attractants are being investigated to determine their role in the maintenance of effective insect control programs. Light, bait, and mechanical traps are being evaluated as control methods and as means of detecting the abundance of insects regularly during the season. Information obtained in such surveys provides a basis for application of insecticide treatment only when necessary.

All feasible methods of insect control are based on the life history and behavior of pest species. Consequently, a large part of the research effort is concerned with fundamental studies. The influence of environmental factors such as temperature, host relationships, light, and other factors on development and mortality of several fruit insects are being investigated. In many instances, laboratory rearing of both pests and their natural enemies is being accomplished to accelerate the acquisition of biological information.

There are 62.5 professional man-years dedicated to research in this area in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. The codling moth was reared continuously through 19 generations on a wheat germ diet at Yakima, Wash. Nineteenth generation moths were indistinguishable from those of the first generation; egg viability remained identical and fecundity was reduced only slightly. No abnormalities were apparent. Up to 97% of the larvae developed to the adult stage when reared individually in small plastic cups or glass vials of at least 1 inch in diameter. In smaller vials, larval webbing trapped and deformed the newly emerged adults. When two or three larvae were implanted per cup, the yields were 68.9% and 65.0%, respectively, but some cannibalism was observed. Some of the individuals exhibited retarded growth when they were not killed by other inhabitants of the same cup.

In a recent modification, trays 15 inches square and 4 inches deep were used for continuous rearing of large numbers of codling moths. The trays were filled to a depth of $\frac{1}{2}$ inch with the rearing medium and 12 hours later eggs were surface-sterilized and implanted en masse on the surface. Egg viability was normal (80%) and 8 to 23% of the first instar larvae completed development. The remainder died without entering the medium. Current production with this method is about 200 moths per day. Methods are being investigated to reduce the larval mortality.

At Vincennes, Ind., the codling moth diet was mixed in large batches for the first time, then apportioned to small plastic cups, and infested with two newly-hatched codling moth larvae per cup. Of 9,800 larvae placed in the cups, 56% developed to the adult stage. Less than one percent of the cups was lost due to mold. Subsequent tests have shown that the use of three larvae per cup may result in at least a 10% increase in adult moth recovery. Pear wood was superior to creased-waxed paper liners in attractiveness as an oviposition substrate. Eggs averaged 52 per adult moth in cages containing pear wood compared with only 21 per adult in cages containing waxed-paper liners. The percent of egg hatch was 59% from pear wood and 53% from waxed-paper liners.

Dissection of female codling moths collected in bait traps at Yakima, Wash., showed that 7.2% were unmated, 56.3% had mated once, 15.5% twice, 8.3% three times, 5.9% four times, and 6.5% five or more times. The maximum number of matings observed was eleven. These data correspond with those in similar studies of females collected in light traps and are consistent with similar data obtained in previous years.

2. Peach Tree Borers. At Vincennes, Ind., larvae of the lesser peach tree borer were reared to adulthood on an artificial diet, consisting of the basic codling moth diet with alfalfa meal and peach wood shavings added. About 50% of the larvae reared on this diet developed to the adult stage. A few individuals of the peach tree borer and the American plum borer were also reared to adulthood on this diet. Last instar larvae of the lesser peach tree borer reared on artificial diet entered diapause. Exposure of the larvae to temperatures between 38 to 40° F. for 40 to 45 days were required to break diapause. The larvae subjected to this time and temperature requirement attained adulthood, mated, and deposited eggs. Recent studies have shown that rearing under continuous light conditions may prevent the borers from entering diapause. The lesser peach tree borer was also reared successfully on small thinning apples, approximately 1.25 inches in diameter. On this host the insects may be reared from egg to adulthood in a period of 40 to 45 days. The average length of head capsules of the lesser peach tree borer was 0.27, 0.45, 0.61, 1.02, 1.36, 1.76, and 2.30 mm, respectively, for instars one through seven. The average length of larvae was 1.20, 2.03, 4.09, 6.63, 11.36, 14.75, and 18.76 mm, respectively, for instars one through seven. Weight of larvae for instars three through seven was 0.0016, 0.0057, 0.0264, 0.0463, and 0.0809 gms. Eggs averaged 0.568 mm in length.

To provide peach tree borers for experimental studies at Fort Valley, Ga., cocoons were placed in sand-filled, screen-covered pans and kept moist. Emerging female moths were placed in cages where they mated with wild males they attracted. Mated females placed individually in 8-pound paper bags with cellophane windows deposited approximately 453 eggs each. Peach tree borer eggs hatched readily when bits of oviposition paper were pinned at the bases of 100 trees with the eggs next to the bark. However, only 1.5 borer adults per tree emerged the following year. When newly hatched larvae were placed on the trunks of peach trees, counts made the following spring indicated less than two surviving larvae per tree. Artificially infesting peach trees as a means of mass producing peach tree borers has not yet been successful.

At Fort Valley, Ga., newly hatched peach tree borer larvae grew vigorously on an artificial diet for 5 to 6 weeks after which growth was slow. Finely ground peach bark was then added to the diet and the larvae resumed active feeding. The larvae pupated but the cocoons molded and only one deformed female moth emerged. Less than 5% of newly hatched peach tree borer larvae, placed on small freshly cut peach roots in moistened vermiculite, emerged as adults. The emerging females were undersized but attracted males and deposited some fertile eggs.

3. Miscellaneous Insect Pests of Deciduous Fruit. At Fort Valley, Ga., peach trees representing commercial and home plantings in several counties as well as a planting on the station grounds were sampled for overwintering curculios. Samples from the station averaged 1.4 curculios per tree and those from home plantings, 0.7. In only one case were curculios taken from a commercial orchard, indicating their virtual absence where spray programs had been followed.

Modifications of the artificial diets used for rearing oriental fruit moth and melon fly were not successful in rearing experiments with the apple maggot at Wooster, Ohio.

4. Pecan and Other Nut Insects. Studies at Albany, Ga., on the effect of two miridae, Plaginothus repletus and Orthotylus ramus, on pecans indicated that the presence of these insects does not contribute to premature nut drop on the Stuart and Schley varieties of pecan.

Hickory shuckworm moths of the last summer generation oviposited readily when fed only distilled water in tests at Albany, Ga. Honey-water lengthened the life span and oviposition period but did not increase egg deposition. Although attempts to rear the hickory shuckworm on artificial media have not been successful, rearing on sprouting pecan nuts may be possible. When shuckworm eggs were placed on sprouting nuts they hatched, the larvae developed in the nut and adult moths emerged in 4 to 6 weeks. In one test 27 sprouted nuts infested with 135 eggs yielded 37 large moths when held at a temperature of 80° F. and 70% RH.

In other experiments at Albany, Ga., to determine the effect of refrigeration on diapausing hickory shuckworm larvae, 50% of the larvae emerged as adults after 26 days at temperatures of 33° to 38° F. The sexes were about equal in number. Fewer larvae reached adulthood when held at these temperatures for longer than 26 days and no moths emerged after 207 days.

Recent observations at Shreveport, La., indicate that the nut casebearer, obscure scale, phylloxera, black aphid, spittlebug, May beetles, shoot curculios, mites, a leaf miner, and possibly the fall webworm, are more prevalent in Louisiana than in Georgia.

5. Insect Vectors of Virus Diseases. Contrary to earlier indications, it was established at Riverside, Calif., that Eriophyes insidiosus, the peach mosaic vector, has a preference for ornamental, flowering varieties of peach. This knowledge will have usefulness in surveying for the vector mite in uninfected peach areas.

At Riverside, Calif., peach mosaic vector mite surveys resulted in the discovery of eight new species of eriophyid mites, all of which have been described.

Preliminary studies at Riverside, Calif., to develop methods of rearing pear psylla revealed that the appearance of summer and winter forms can be manipulated by regulating the photoperiod. When held in constant temperature cabinets, lighted at an intensity of 100 foot-candles, populations of psylla eggs and nymphs produced adults of the winter form when they received less than 14-hours' exposure to light per day.

At Corvallis, Oreg., Colladonus geminatus and C. montanus, leafhoppers which transmit western-X virus of peach and cherry, are under study to determine whether they are capable of transmitting little cherry virus. In diapause studies, C. montanus reared under 16-hour photoperiods laid eggs which hatched without delay; those reared under 8-hour photoperiods laid eggs but only a few hatched after six weeks. C. geminatus did not require specific photoperiod conditions for continuous development but were difficult to maintain, probably because of light conditions inadequate to produce suitable host plants for supporting their development.

B. Insecticidal and Cultural Control

1. Codling Moth. In laboratory screening tests against codling moth larvae at Yakima, Wash., Geigy GS-13005, Chipman RP-11783 and Niagara NIA-10242 were nearly as effective as the standard treatment of Guthion. Geigy GS-13005 and Shell Development SD-9129 were tested against codling moths in orchard plots and were as effective as the Guthion standard. However, Shell Development SD-9129 caused severe burning of apple leaves.

At Vincennes, Ind., Chipman RP-11783, Bayer 52553, and Upjohn U-20493, all at 4 ounces active material per 100 gallons, were 100% effective in preventing codling moth entries into thinning apples in the laboratory. Seven other compounds tested were of a lower order of effectiveness and not considered promising.

The effect of normal weathering of various insecticides on apples was determined by the field-laboratory bioassay method at Vincennes. Malathion (57 EC) plus American Cyanamid AC-52160 (4 lbs/gal EC), Guthion (25 WP), Niagara 10242 (50 WP), Geigy GS-13005 (40 WP), Shell SD-9129 (3.2 lbs/gal WS), carbaryl (50 WP), General Chemical 6506 (25 WP) were applied as cover sprays at 3 weekly intervals, beginning May 11. Four-hour-old deposits of all treatments were 100% effective against larvae of the codling moth. After 7 days of weathering, carbaryl, Guthion, and Shell SD-9129 had efficiencies of 99, 98, and 96%, respectively. After 14 days of weathering, Shell SD-9129's mean efficiency was 97%, and 73% after 21 days. The remaining compounds were much less effective at concentrations and intervals tested. There were no apparent significant differences in efficiency related to variety. Four-hour-old deposits of all treatments gave 100% mortality of adults after 24 hours exposure to treated foliage. Guthion and malathion plus AC-52160 were highly effective against the adult moths after 24 hours exposure to 7-day-old deposits while Geigy 13005, Niagara 10242, carbaryl, Shell SD-9129, and General Chemical 6506 were less effective. With the

possible exception of Guthion, none of the 14-day deposits gave significant adult mortalities.

At Kearneysville, W. Va., Chloropropylate and UC-19786 each gave good control of codling moth but were not equal to Guthion or carbaryl.

2. Orchard Mites. The following materials showed promise in laboratory screening tests against two-spotted spider mites at Yakima and Wenatchee, Wash.: Bayer 47416, 47940, 51295, 52553, and 54203; Geigy GS-12968, FL-342, and GS-13005; Chemagro 4671, 4738, and 4835; Commercial solvent P-252; Hercules 9326, 14503; Hooker HRS 1631; Monsanto 19203, 42320; Niagara 9241; Shell SD-9129; Spencer S-6900; Stauffer B-10228, N-3338, N-4372, N-5117, and R-8033; Thompson-Hayward TH-113-M; Thiocron; Upjohn 7175, GHS 146; U. S. Rubber BL-1310, BL-1311, BL-1315, DO 14; and Virginia-Carolina 3-665.

In orchard tests at Yakima, Wash., against mcdaniel mites, Union Carbide 19786 and 20047-A, Morestan, Bayer 37344, and binapacryl were effective. Binapacryl and Bayer 37344 were effective against European red mites.

Of 28 compounds screened at Vincennes, Ind., Hercules Powder 13843, Stauffer N-5117, Thompson-Hayward TH-113-M, Spencer Chemical S-6900-A3, and Chipman Chemical RP-11974 were promising enough to warrant further tests. Stauffer R-8033 and Velsicol OCS-21959 were not efficient foliar acaricides, but they showed considerable systemic activity.

At Vincennes, Ind., Morestan formulated as a dust or spray gave good control of European red mite, with no apparent difference between the two formulations. The compound caused mild phytotoxicity, but this was not considered a limiting factor. Binapacryl (50 WP), Morestan (25 WP), chlorobenzilate (25 WP), Chloropropylate (25 EC), tetradifon (12.5 EC), and Kelthane (18.5 WP) gave good control of orchard mites on 3 apple varieties when applied as 2 mid-summer treatments at weekly intervals.

At Kearneysville, W. Va., Morestan, Chloropropylate, and UC 19786 each gave outstanding control of European red mite in seasonal spray schedules. Each material markedly reduced hatch of mite eggs and maintained active mites at sub-economic levels.

In Poland (PL 480 project E21-ENT-5) Panonychus ulmi and Bryobia rubrioculus developed resistance to parathion and malathion sooner than to Meta-Systox-R and other systemic compounds under orchard conditions. This resistance pattern is similar to that which has occurred in the United States and in other countries.

3. Pecan Insects. In field trials at Albany, Ga., Guthion (25 WP) was superior to malathion (25 WP), parathion (15 WP), and EPN (25 WP) for black pecan aphid control. Malathion and parathion lost their effectiveness in 2 weeks, EPN in 4 weeks, but Guthion was still effective after 7 weeks.

EPN, Bayer 44646, Banol, and endosulfan were very effective against the pecan leaf casebearer. However, only the standard, EPN, was effective against the hickory shuckworm. In other field tests, 5 applications of the fungicides zineb and Du-Ter were comparable with 1 application of malathion for control of the pecan leaf casebearer.

Soil applications of Di-Syston granular at the rate of 3 pounds actual per acre were ineffective against the pecan leaf casebearer, the black pecan aphid, two yellow aphids, and Monellia sp.

4. Insect Vectors of Virus Diseases. At Riverside, Calif., application of diazinon in an experimental peach orchard at petal fall for control of the peach mosaic vector mite was continued for the fifth successive year. The spray program has virtually stopped spread of infection despite the presence of untreated diseased trees.

At Fort Valley, Ga., a spring application of 10, 30, or 50 grams of 10% granular Bayer 25141 to young peach trees controlled leafhopper vectors of phony peach virus disease and also gave 92, 94, and 97% respective reductions of terminals infested by oriental fruit moth larvae.

5. Miscellaneous Insect Pests of Deciduous Fruits, Nuts, and Berries. Application of 2% 60-viscosity oil on apples at the prepink stage failed to prevent a heavy infestation of San Jose scale from developing in Indiana. Application of 2% 70- and 100-viscosity oils at prepink and 2% 70-viscosity oil at the late dormant and pink periods gave substantial reduction in scale infestation.

At Vincennes, Ind., the effectiveness of insecticides after normal weathering was determined for the red-banded leafroller. As with the codling moth, four-hour-old deposits of all treatments were 100% effective against the larvae. After 7 days of weathering, the treatments gave the following average percent efficiencies: Guthion, 100; Geigy 13005, 100; carbaryl, 98; malathion + AC-52160, 97; Niagara 10242, 95; Shell SD-9129, 82; and General Chemical 6506, 67. After 14 days of weathering, malathion plus AC-52160 showed a mean efficiency of 91% and Guthion, 88%. The remainder of the treatments were much less efficient. After 21 days, malathion plus AC-52160 showed a mean efficiency of 77%; the remaining treatments were below 30%. Four-hour-old deposits gave 100% mortality of adults after 24-hour exposure to all treatments except General Chemical 6506, which gave 98%. After 7 days, Guthion, Niagara 10242, and malathion plus AC-52160 were effective adulticides but none of the compounds were effective after 14 days.

In laboratory screening tests at Wenatchee, Wash., Bayer 25141, 38156, 39197, 45556, and 47940; General Chemicals 9879, Hooker HRS 1667 and 1694; Hercules 9326; Naugatuck C912; Niagara 9241 and 10242; Shell Development SD-9129; and Stauffer N-3794 and R-8033, were effective against the green peach aphid.

At Fort Valley, Ga., Stauffer R-5092 and Imidan used at the rate of 1.5 pounds 50% wettable powder per 100 gallons of water gave 98 and 99% mortality of plum curculio, respectively, for 10 days after application. Effectiveness of both compounds declined rapidly during the succeeding 2 weeks. A single application of endrin at 2 pounds actual per 100 gallons as a post harvest trunk spray was highly effective in preventing peach tree borer infestation.

At Kearneysville, W. Va., Bayer 44646, Geigy 13005, and endosulfan effectively controlled lesser peach tree borer larvae.

At Wooster, Ohio, bait sprays of vegetable protein hydrolysates and malathion reduced apple maggot infestation in home garden orchards. Application with power equipment gave better control than when knapsack sprayers were used. Soil surface treatments with 10 pounds actual granular dieldrin per acre effectively reduced the number of emerging apple maggot and walnut husk fly adults. Tilling the dieldrin into the soil or increasing the dosage rate to 15 pounds per acre gave no increase in effectiveness. Fifteen percent of walnut husk flies emerging over a two-year period emerged the second year. Three applications of carbaryl plus malathion applied at 7-day intervals gave complete control of blueberry tip borer in blueberries. In studies to find powdery mildew fungicides that are compatible with carbaryl for grape insect control, folpet was the only effective material.

C. Insecticide Residue Determinations

Residues on or in fruit or foliage following insecticide applications were determined by chemists at Beltsville, Md., and Yakima, Wash. Washington pears sprayed with Guthion or Perthane 14 days before picking were divided into four lots. One was analyzed immediately, two kept in storage at 34° F. for 7 and 17 days, respectively, and the remaining lot held in storage for 7 days, then at room temperature for 24 hours and finally allowed to ripen at 75° F. and 60% humidity. The Guthion-treated lots contained 1.02, 0.93, 1.04, and 0.75 ppm, respectively, of Guthion. The Perthane-treated lots contained 1.66, 1.81, 2.01, and 2.01 ppm, respectively, of Perthane. In storage tests conducted the previous year, there had been a greater loss of insecticide during storage. In other tests, pears sprayed with Guthion wettable powder showed a residue of 1.38 ppm when picked 13 days later. Other mature pears sprayed with either a liquid concentrate or a wettable powder of Perthane had residues of 3.98 ppm and 0.90 ppm, respectively, 13 days after treatment.

Analysis of Indiana apples sprayed with binapacryl or Morestan showed that binapacryl residues declined to the minimum detectable level, 0.10 ppm, 21 days after treatment; the Morestan residues persisted in measurable quantities for at least 60 days after application.

Nut meats from Georgia pecan trees grown in soil treated with Di-Syston did not contain any detectable amount of this material at harvest time.

Samples of green Costa Rica coffee beans from trees grown in soil treated with Di-Syston or Bidrin showed no residues of either material above the

natural background of untreated coffee. Samples of Brazilian coffee treated with dieldrin contained 0.02 ppm of dieldrin in the hulls, but samples of depulped and dry pod coffee contained less than 0.01 ppm, the limit of sensitivity of the analytical method.

D. Biological Control

1. Aphids and Scale Insects. Coccinellid beetles were highly susceptible to standard dosages of nicotine sulfate and the organophosphates, Meta-Systox, "Intration," "Sayfos" (probably menazon), morphothion, and Folithion applied for control of Aphis pomi, in studies conducted in Poland (PL 480 project E21-ENT-2). Other predators, including anthocorids, syrphids, and cecidomyids, and the hymenopterous parasites Praon sp., Ephedrus sp., and Trioxys sp., were less severely affected. Reduced dosages of these compounds enhanced survival of all the predators and parasites studied, indicating the possibility of integrated control.

2. Orchard Mites. Studies in Poland (PL 480 project E21-ENT-8) showed that although high populations of the predaceous mite, Typhlodromus finlandicus, are present on apple foliage at the time of leaf drop, only about 10% survive until the following spring. Most of the mites fall to the ground with the leaves and fail to reach safe hibernating quarters under loose bark of the trunk or twigs. T. finlandicus was reared to adulthood in the laboratory on pollen or on the gall mite Aculus schlechtendali, but the adults did not oviposit. When held on clean leaves, the mites did not develop beyond the deutonymph stage.

3. Berry Insects. Small numbers of the predaceous mite Typhlodromus fallacis, present in Beltsville, Md., plots sprayed with aphicides in the fall of 1964 destroyed most Tetranychus telarius eggs as the latter were laid the following spring. By harvest time the number of fallacis mites varied from 0 to 7 per leaf while host mites averaged 0.1 per leaf on unsprayed plots. Acaricide-resistant telarius mites from experimental plots, receiving an intensive aphicide spray program, failed to build up in the unsprayed plots because of fallacis mites, suggesting that spider mites on strawberry plantings increase in importance when predator mites are destroyed by aphicides. Introductions of the predaceous mite Phytoseiulus persimilis at the rate of 200 per 10 feet of row failed to become established on strawberry plots heavily infested with spider mites.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Codling Moth. Moths sterilized with tepa and then released into an isolated apple orchard in 1965 in Washington were very active and were caught in large numbers in bait traps, light traps, and sex attractant traps. In sexual aggressiveness tests conducted in the laboratory, female moths caged without males lived 9 days but only 6 days when caged with male moths at a 1:1 ratio. As the ratio of male to female moths increased, the female longevity decreased. Female longevity was also positively correlated

with increasing dosage of the sterilizing treatment the males had received. The longevity of females caged at a ratio of 3 untreated males to 1 female was 5 days; with males treated with 40 kr of radiation or 15 µg tepa, 6 days; and 30 ug tepa, 9 days. In preliminary tests to develop methods of mass treatment with chemosterilants, male moths were attracted through a glass tube in which the inner wall was treated with tepa. When males treated in this manner were mated with untreated virgin female moths, reductions in egg hatch were consistent with changes in the dosage used. The sequence in which normal female codling moths were mated with normal and sterile males affected the percent egg hatch. When females mated first with normal males, then with sterile males, 13% of the eggs hatched; but when mated first with sterile males and then with fertile males, egg hatch was 41%.

At Wenatchee, Wash., the antibiotics actinomycin D, cytovirin, hygromycin B, sheptovitacin A, cytovirin and amphotericin A reduced codling moth oviposition.

Codling moth sex attractant was extracted from female moths with various solvents at Yakima, Wash. The attractant was also collected from air passing over female moths or by washing glass surfaces on which female moths had rested. A plastic cage used to contain live female moths remained attractive to male moths for 6 days after the females were removed. In laboratory bioassays, the males became more responsive to attractants as the purity of the latter increased. The same was true in orchard tests when the attractants were placed in the orchard during the flight period at about 9:00 pm. When extracts were placed in the orchard at mid-day, crude extracts of complete moths were most attractive, followed by crude extracts of the tips. More purified extracts did not attract moths, probably because they had volatized before the moth flight. In field cages traps containing 5 live virgin females each caught 3 times as many male moths as traps containing extracts of 50 virgin females each. In orchard tests the live-female traps caught 8 times more males than did the traps containing extracts. Live-female traps also caught many more moths and at an earlier date than did light traps or bait traps. Field cage tests indicated a large variation in the attractiveness to males by individual females.

Nine previously screened candidate insect attractants, supplied by Pesticide Chemicals Research Branch, were retested at Vincennes, Ind., as codling moth adult attractants. Of these, 3 showed promise in olfactometer tests.

2. Lesser Peach Tree Borer. At Vincennes, Ind., 10.3 cords of infested peach wood yielded a total of 4,427 adults, which emerged from May 6 through June 30, 1965. Of the total, 47.6% were females. The moths were used in attractant studies. In 1964, live virgin female traps were utilized to attract male lesser peach tree borers in a block of 235 peach trees, located approximately one mile from the nearest peach orchard. Indications were that males were attracted, not only from the block in which the females were placed, but also from surrounding orchards. In a continuation of the

study in 1965, a total of 579 males were taken during May and June from five trap locations within the test block. In 10 traps placed around the periphery of the test block at distances of ½ to 1 mile away, captures totaled 873 males during the same period.

3. Miscellaneous Insect Pests of Deciduous Fruits and Nuts. At Vincennes, Ind., extracts secured by washing red banded leafroller females with either methylene chloride or ethyl alcohol, or by macerating whole female insect bodies in either of these solvents, elicited strong mating responses from the males when presented with dried residues of these extracts. The methylene chloride wash elicited the strongest response, followed by the macerates in methylene chloride and ethyl alcohol. In olfactometer tests, twice as many male moths were recovered from the sex pheromone source as from the blank source, and methylene chloride extracts were far superior to the alcohol extracts.

Tepa, apholate, tretamine, ENT 50173 and ENT 50611 reduced oviposition by pear psylla in tests at Wenatchee, Wash. Pactomycin, Ampicillin trihydrate, 2-thiouracil, and apholate caused reduced oviposition by the green peach aphid.

At Albany, Ga., 2% apholate sprayed on hickory shuckworm moths effectively sterilized males and females, without increasing mortality over untreated moths.

A mixture of vegetable protein hydrolysate, dibasic ammonium phosphate and benzoate of soda in water was superior to 14 other mixtures in attracting apple maggot adults to sticky board traps at Wooster, Ohio. Deadline, Stikem, and Tanglefoot were equally effective as the sticky material used on the sticky board type traps. Walnut husk fly adults were attracted in about equal numbers to the same protein hydrolysate mixture that attracted apple maggots, and to straight 28% aqua ammonia.

F. Evaluation of Equipment for Insect Detection and Control

1. Pecan Insect Control Equipment. In tests at Shreveport, La., aerial applications of parathion and malathion were erratic in controlling the black pecan aphid and the mite, Eotetranychus hicoriae. Kelthane (18.5% WP) at 2 pounds or chlorobenzilate (50 E or 4 lb/gal) at one pint per 100 gallons of water, applied as standard dilute sprays with an air blast sprayer, gave effective control of the mite. Sampling of a pecan orchard for pecan nut casebearer infestation, following the aerial application of 10 pounds of parathion 15% WP plus 5 pounds 50% DDT WP, in 20 gallons of water per acre, showed an infestation of 4% in the treated block and 37% in an adjacent untreated block.

G. Insect Vectors of Diseases

1. Pear Decline. At Riverside, Calif., vector tests with pear psylla added a significant number of apparent pear decline transmissions from affected field trees to potted pear trees, plus transmissions from the reacting potted trees to new healthy potted trees. Parallel feeding tests in which pear psylla had not been allowed to feed on decline-affected trees before being caged on potted trees showed that the test trees could be killed or caused to decline markedly only by extremely dense populations of the insect. The additional evidence for the viral-cause hypothesis for pear decline was the result of an improved virus indexing technique. When potted trees in which decline symptoms had appeared following exposure to pear psylla in vector tests were joined by approach grafts to healthy trees, with all insects eliminated, the healthy trees reacted promptly with decline symptoms. Healthy trees similarly joined to other healthy trees elicited no reaction. The approach-graft technique came after bud implantations from diseased trees into healthy produced few transmissions or reactions within a 1- to 3-year period of observation.

2. Miscellaneous Stone Fruit Virus Diseases. A new, as yet unnamed, damaging, rapidly spreading virus of cherry was readily transmitted by several species of aphids at Corvallis, Oreg., a unique situation with woody-plant viruses. Aphids incriminated as vectors were Myzus cerasi, Aphis pomi, Acyrthosiphon pisum, Myzus lythri, Macrosiphum rosae, Myzus persicae, and Aphis craccivora. The green peach aphid, Myzus persicae, was found to transmit the virus only during the first hour after removal from infected plants.

At Fort Valley, Ga., Oncometopia nigricans was confirmed as a vector of phony peach disease in 1962. Two more trees inoculated by viruliferous O. nigricans adults in 1961 were confirmed as being infected in the spring of 1965 when transverse root sections gave positive reactions to the acidulated methanol test.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Pollard, Herschel N., and Carroll E. Yonce. 1965. Significance of tibial spines relative to oviposition processes by some leafhoppers (Hemiptera: Cicadellidae). Ann. Entomol. Soc. Amer. 58: 594-5.

Wilson, Norton S. 1965. A new species of blister-forming Eriophyid mite on pear. Ann. Entomol. Soc. Amer. 58: 327-30.

Insecticidal and Cultural Control

Agr. Res. Serv. and Fed. Ext. Serv. 1965. Suggested guide for the use of insecticides to control insects affecting crops, livestock, and households 1965. USDA Agri. Handbook No. 290.

Cleveland, Merrill L. 1964. Acaricide studies at Vincennes, Ind., 1963. N. Cent. Br. Proc. Entomol. Soc. Amer. 19: 139.

Cleveland, Merrill L. 1964. Techniques used in evaluating acaricides for deciduous fruit trees. Proc. 1st Intern'l. Cong. Acar. Extrait de Acarologia, Tome VI (fasc. hors. ser.): 404-8.

Hamilton, D. W., and M. L. Cleveland. 1964. Periodical cicadas in 1963, brood 23. Proc. Ind. Acad. Sci. 1963, 73: 167-70.

Murphy, R. T., Jack E. Fahey, and E. J. Miles. 1964. DDT residues in southern Indiana orchard soils in 1963. Entomol. Soc. Amer., Proc. N. Cent. Br. 19: 144-8.

Still, G. W., and R. W. Rings. 1965. A guide to insect pests and damage to eastern grapes. Ohio Agr. Expt. Sta. - Res. Summ. 2. Fr. Cr. Res: 17-20.

Insect Sterility, Attractants, and Other New Approaches to Control

Cleveland, M. L., and L. L. Murdock. 1964. Natural sex attractant of the lesser peach tree borer. J. Econ. Entomol. 57: 761-2.

AREA NO. 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Insects and mites that attack citrus and subtropical fruits reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase cost of production. There is a continuing need for research to secure biological and ecological information on these pests that will provide a better basis for the development and implementation of insect control methods than that now available, or suggest additional non-chemical approaches to their control. Additional research is needed on biological control agents, including parasites, predators, and pathogens and on methods for more effectively integrating biological, chemical, and other control measures. Safer, even more effective and economical control procedures that will minimize or avoid objectionable chemical residues and problems associated with residues should be developed. The research on attractants, chemosterilants, sterilization techniques, and genetic methods need increased attention. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research to provide effective low-cost detection methods, processes for destroying insect infestation in fresh fruits and vegetables intended for shipment to uninfested areas and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. This program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research and Plant Pest Control Divisions; at Hoboken, N.J., in cooperation with the Plant Quarantine Division; at Mexico City, Mex., in cooperation with the Plant Pest Control Division and with the Direccion General de Sanidad Vegetal of the Mexican Secretaria de Agricultura y Ganaderia and on the islands of Guam and Rota in cooperation with the Territory of Guam, U. S. Navy, and the Trust Territory of the Pacific Islands. Work was initiated in 1964 in San Jose, Costa Rica, on the Mediterranean fruit fly with funds supplied by the Agency for International Development (AID) in cooperation with the Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA) and with the Interamerican Institute for Agricultural Sciences at Turrialba, Costa Rica. Research formerly conducted in cooperation with the Florida Agricultural Experiment Station at Lake Alfred was transferred to the Orlando, Fla., and Weslaco, Tex., laboratories in January 1965.

The Federal scientific effort devoted to research in this area totals 29.3 professional man-years. Of this number, 7.3 is devoted to basic biology, physiology, and nutrition; 2.7 to insecticidal control; 1.1 to insecticide residue determination; 2.3 to biological control; 10.0 to insect sterility, attractants, and other new approaches to control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.1 to varietal evaluation of insect resistance; 0.5 to insect vectors of diseases; and 1.3 to program leadership.

PL 480 research grants include India (A7-ENT-26) Biology of gall midges affecting mangoes with special reference to extent of damage; India (A7-ENT-35) Biology of gall midges affecting citrus plants with special reference to the extent of damage; Pakistan (A7-ENT-5) Studies on scale insects, fruit flies, and mites and their natural enemies in West Pakistan; Greece (E11-ENT-1) Control of the olive fly with radiation or chemical sterilization procedures; Egypt (F4-ENT-3) Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on citrus and other subtropical fruit insects. Attempts to establish more effective complexes of biological control agents have led to the importation of new natural enemies from other areas of the world, the most promising of which are being reared in quantity and colonized in the field. The influences of adverse factors on native and imported biological control agents is being determined by correlation of field population counts with weather cycles and pest control treatments and by laboratory studies of temperature, humidity and other factors.

Injurious species are being studied to ascertain the type and extent of damage produced by each, methods of predicting outbreaks, mass rearing methods, seasonal population fluctuations and other biological information upon which integrated control measures may be based.

New insecticides are being evaluated to determine the most effective methods of application, dosages, compatibility with other materials, phytotoxicity, effect on beneficial insects, safety of application and residue levels on and in fruit. Particular attention is being devoted to spray oils because of the safety of their use and the fact that no evidence of resistance has appeared in any of the insect pests for which they are being used.

New techniques for sterilization of citrus and avocado fruits against fruit flies are being evaluated, so that the produce may be moved from quarantine areas into uninfested areas without containing harmful residues.

The total State scientific effort concerned with citrus and subtropical fruit insects is 19.7 professional man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. Brown soft scale in citrus plantings in Texas failed to increase during May and June as in previous years. Infestations were at their lowest seasonal level since 1962 when a severe freeze caused extensive damage to citrus trees and reduced scale populations. In June 1965 scale counts averaged only 0.005 scale per leaf. In June of 1964 mean infestation was 1.9 per leaf. Parasitism was low in both years suggesting that factors other than parasites may have been responsible for the 1965 decrease. In past years heavy scale infestations followed soon after the start of cotton spraying on a 4- to 7-day application schedule. Drift from methyl parathion has been suspected as a factor contributing to the brown soft scale problem. One explanation for failure of brown soft scale infestation to increase as expected may be the possibility of less drift because of extensive use of low-volume formulations.

At Hargill, Tex., a 380-acre orange grove was sprayed by plane on May 2 with 2 pounds active methyl parathion per acre. On June 21 brown soft scale infestations averaged about 2 scales per leaf. The highest infestation in 21 Lower Rio Grande groves surveyed in June was 0.04. An additional methyl parathion spray to a portion of the Hargill grove caused the scale population to increase 250% in two weeks, while in a portion of the same grove not sprayed the second time, the increase was only 24%.

In a cooperative study with the Soil and Water Conservation Research Laboratory at Weslaco, infra-red aerial photography showed promise as a quick and effective method to determine presence of heavy scale infestation on citrus in large area plantings. Observations in groves verified that individual trees with heavy scale infestations could be identified with aerial photographic techniques.

In dispersal studies of the citrus red mite at Riverside, Calif., on orange trees in the field, the adult female was the predominant dispersal stage, representing 80% of all motile forms recovered. Sixty-three percent of the total mites recovered had moved upward, 22% horizontally, and 15% downward from points of release. At a mean temperature of approximately 70° F maximum known dispersal was 8 feet in 2.5 weeks; at 50° F it was 3 feet for the same period. One hour after simultaneous release of both albino and red strains on lemon shoots with little foliage to impede movement, 4 and 3% of the total red and albino mites, respectively, were recovered between 3 - 4 feet above the points of release.

Plastic, paraffin, animal membrane, cellophane, and vegetable cellulose films were tested at Riverside, Calif., to develop procedures for rearing the citrus red mite on artificial media. Only cellulose films provided a satisfactory surface on which the mites would remain and feed. Albino mites of all stages were placed on membranes and examined for feeding on 10%

sucrose solution containing red food dye. Immature forms fed through thin paraffin or cellulose as shown by the presence of the dye in the mites. Millipore® filters adhering to vegetable parchment provided the most satisfactory surface. All mites including newly hatched larvae, fed through this membrane and many molted successfully with some immatures developing to adults.

Life span of male California red scales at Riverside, ranged from 2 to 60 hours, with a half life of approximately 6 hours. Individual males introduced into cages of virgin females fertilized an average of 15 females with a range of 0 to 30. Under artificial illumination, mating occurred during the entire 24-hour day. Females became attractive to males shortly after the start of the gray adult stage and remained attractive as long as they were unfertilized. Within 24 hours after fertilization the pygidium was retracted and the female no longer elicited male response. Multiple matings with 2, 4, and 8 different males did not increase the biotic potential of individual females.

In Florida differences in susceptibility to feeding on citrus seedlings by citrus bud mites (Aceria sheldoni) was demonstrated in the laboratory. Florida sweet seedling, Key lime, and Duncan grapefruit exhibited feeding damage after 3 weeks. After 7 weeks, these varieties, plus pineapple, Cleopatra, Temple, and Murcott showed symptoms of severe bud mite injury, consisting of shortening of internodes, multiple bud growth, witches-broom, and leaf cupping. Troyer, Trifoliata and Carrizo had no damage symptoms until 21 weeks after infestation.

2. Subtropical Fruit Flies. Olfactometer tests in Hawaii revealed that a sex pheromone may be produced in the male and not the female oriental fruit fly. Sexually mature, unmated, normal oriental fruit fly females had a strong short-range attraction to males against a 2 mph airflow. In Hawaii, male oriental fruit flies irradiated as pupae lived the same length of time as normal laboratory-reared flies, but the normal female flies died at a greater rate than irradiated females. After 6 weeks the surviving male/female ratios were 3.4/1 for normal flies compared to 0.94/1 for irradiated.

In Hawaii about 15% of (picked) ripe coffee cherries were found infested by the Mediterranean fruit fly. Fruit from coffee trees encased in fiber glass screen cages with or without flies was harvested and graded 10 times in the 6-month producing season. The percent by weight of cherry coffee in No. 1 grade ranged from 14 to 67 from infested trees and 89 to 100 in the uninfested. Much more unrecoverable loss by dropping was associated with infested cherries. Defects included fruit with withered or hardened skin, decayed pulp, moldy pulp, and less than 1.0 specific gravity. Formerly the berries were harvested before those infested dropped or developed defects, but higher labor costs now prevent frequent picking. Possible adverse effects on taste and size of bean require further study.

Oriental fruit fly attack on ripening papaya under controlled conditions in Hawaii produced a positive correlation between infestation and Rhizopus infection, the disease incidence being increased 10X. Anthracnose was cultured from the bodies of 15% of field-collected flies and parasites, suggesting that under favorable conditions the insects may be involved in the spread of this disease.

In Mexico three male Mexican fruit flies were recaptured 9 to 11 months after release. One male was recaptured in the same grove in which it was released and the other two in a grove located approximately two miles away from the release point.

In mass rearing the Mediterranean fruit fly at San Jose, Costa Rica, addition of 0.1% each of tegocept and sodium benzoate to the larval rearing medium effectively controlled severe fungus contamination which had sharply curtailed the rearing program. During the period January to March 1965, a total of 33,245,120 pupae were recovered from 156,360,000 eggs for a mean yield of about 21%.

A method was devised for automatically marking flies for sterile male releases by allowing them to contact a fluorescent powder with their ptilinum as they emerge from the puparia. The powder, which is non-water-or alcohol soluble, fluoresces readily under ultraviolet radiation after the ptilinum has been retracted into the head.

The number of pupae placed in the release stations, which consist of fiber cotton containers measuring 43 cm in diameter and 35 cm in height, was found to be the major factor responsible for excessive mortality of sterile Medflies released at Puntarenas. Post-emergence adult mortality increased more than 6-fold when the number of pupae per station was increased from 25,000 to either 50,000 or 80,000. The mortality at the higher pupal concentrations was the result of injury brought about by overcrowding and competition for the available resting surfaces required by newly emerged adults. Prevailing ambient and within station temperatures were investigated and eliminated as a factor contributing to the mortality problem. In recent tests, insertion of dried tropical almond leaves in the release stations to provide additional resting surface for the newly emerged flies reduced the mortality from 50 to 4%, even where 50,000 pupae per station were employed.

Research in Greece under PL 480 Project E11-ENT-1 showed that gamma ray doses of 6, 8, 10, and 12 kilorad, applied to the advanced pupal stage of the olive fruit fly (Dacus oleae), effectively sterilized the adult males without affecting their longevity. These doses also caused permanent sterility in the females.

In Egypt under PL 480 Project F4-ENT-3 outstanding progress was made during the past year in developing a technique for mass rearing the Mediterranean fruit fly. An earlier problem of contamination of the larval rearing medium with phorid flies was resolved by rigid sanitation procedures. Production

of up to 400,000 Medfly eggs per day has been demonstrated with present rearing techniques.

3. Southern Green Stink Bug. In Hawaii improved methods were developed for mass producing the southern green stink bug that provide a 25X population increase per generation (5 weeks) at a cost of approximately 5 man hours labor and $1.75 for food per 1,000 adults. The best nymphal diet consisted of soaked and waxed raw seeds of garbanzo and peanut. The bugs were found to have gregarious feeding habits before each molt. Special manipulation and cage design were necessary to take advantage of this habit. Crumpled paper towels provided ample resting space before the final molt. Water had to be provided when dry or soaked seeds were fed but not when succulent materials (cabbage, green beans, fresh corn, etc.) were supplied. Wild bugs deposited twice as many eggs (100 per female) as laboratory reared bugs.

B. Insecticidal Control

1. Citrus Insects and Mites. In the laboratory screening program of new chemicals against California red scale at Riverside, Calif., 2 compounds with lower mammalian toxicity than parathion were as effective as parathion in initial toxicity and residual activity. These were Stauffer N-4446 and R-5763.

In field evaluation studies at Orlando, Fla., GC 9160 gave almost complete control of citrus rust mites for 3 months but was ineffective against Texas citrus mites (Eutetranychus banksi). Stauffer N-4543, ethion plus oil, and Pentac were the most effective materials for control of Texas citrus mites. GC 9160 and chlorobenzilate failed to control Texas mites, while zineb caused a marked increase in Texas mites.

C. Insecticide Residue Determinations.

1. Citrus Insects and Mites. Drift of methyl parathion into Texas citrus groves from airplane sprays was determined by analysis of deposits on foliage and on filter paper on horizontal stands at various distances in the grove downwind from line of flight. Methyl parathion was applied at the rate of 0.5 lb. actual insecticide per acre and determined following 10 plane passes along a single line of flight. Deposits of methyl parathion on leaves ranged from 4.42 ppm at a distance of 110 feet downwind to 0.2 ppm at 1380 feet downwind. Deposits on filter paper ranged from 277 micrograms per square foot at 110 feet to 3.6 per square foot at 1380 feet.

Bioassay measurements of drift conducted with parasites and predators in screen-cages showed complete kill of Aphytis proclia, a chaff scale parasite, 400 feet downwind from the spray source and 77% mortality at 1380 feet. Lacewing adults were unaffected when exposed in the same manner but were killed when exposed to methyl parathion deposits on citrus terminals.

Drift of low-volume and high-volume application of malathion by airplane was compared in Texas. From 2 to 3 times as much technical as dilute material was deposited directly below the flight line, but drift from both formulations was recorded at 1400 feet downwind - the maximum distance tested. It was shown that 2.4 times more malathion from technical formulations than from the dilute came down in sampling stations within a 1400 foot test area. This may indicate that more spray from the dilute formulation was broken up into very fine particles that could have been carried aloft and drifted beyond the test site. In bioassay tests with Aphytis proclia, drift from both formulations caused complete kill 500 feet downwind.

D. Biological Control

1. Citrus Insects and Mites. Eleven species of parasites and 2 hyper parasites have been reared from brown soft scale collected in lower Rio Grande Valley groves. Of these, the following are new Valley records: Encyrtus infelix (Emb.), Aphycus pulvinariae How., Encyrtus bicolor (How.), Anicetus annulatus Timb., Microterys flavus (How.), and a Pseudaphycus sp., Coccophagus lycimnia comprised over 90% of adult parasites reared from scales collected in valley groves.

Sampling of groves exposed to insecticide drift from nearby cotton plantings show fewer coccinellids and lacewings on trees closest to cotton, indicating that they may be affected by drift.

Field studies with caged citrus trees showed outstanding control of brown soft scale by coccinellids. Scale counts on 5 1-foot grapefruit terminals showed that 500 adult Chilocorus cacti (L.) had reduced scale 95% between July and December, from 9607 to 448. In counts on a tree caged with 1000 adults of the dominant brown soft scale parasite, C. lycimnia increased 438% from 430 to 18,858. In counts on a caged check tree scales increased 1081% and, before the final count, the tree was killed by scale. On an uncaged check tree, scale decreased 77% from 9909 to 2309. Parasitism on this tree reached 23.5%, which was from 3 to 6 times greater than on any of the trees under test. Predators entering the grove probably helped in the natural reduction of scale on the uncaged tree. If parasites had been responsible for the scale decrease on the uncaged tree, then parasite populations in the grove must have eventually exceeded 1000 per tree. This number released on one of the caged trees failed to control scale and permitted a 438% increase.

At Riverside healthy citrus red mites lived 2 to 3 times longer and laid 6 to 30 times as many eggs as mites infected with a virus diseases. The albino and normal red strains of mites reacted similarly to the disease. Within 24 to 48 hours following spraying with a virus suspension, inoculated mites were able to transmit the virus to healthy mites. Transmission continued as long as inoculated mites were alive. Transmission also occurred in cases where inoculated mites produced no birefringent crystals, further indicating that not all infected mites produce crystals.

Citrus red mites were infected with the virus disease by feeding through inert polyethylene membrane on suspensions of triturated diseased mites in 10% sucrose solution for 2, 6, or 24 hours. Mites were allowed to feed for 6 hours through the membrane on dilutions of the virus ranging from 1 mg of triturated diseased mites per 1 ml of 10% sucrose solution to 1 mg to 1000 ml. There was a gradual decline in infection from 50% with a 1:1 dilution to 11% with a 1:1000 dilution.

Populations of citrus red mite increased to economic levels when application of the virus suspension by sprays or introduction of inoculated mites into 3 field plots at or near Riverside, Calif., were suspended. A single re-treatment resulted in reduction of the population to subeconomic levels.

Healthy and virus-inoculated albino mites released simultaneously in adjacent navel orange trees at Riverside, dispersed up to 5 feet in 2 days for healthy mites and 6 feet in 4 days for virus inoculated mites.

During a field epizootic of the virus disease of the citrus red mite in a 12.5 acre lemon grove near Riverside, Calif., the initial mean population of 68 eggs, 35 immatures, and 6 adults per leaf in January 1965 gradually diminished to a mean of less than 1 immature motile form per leaf and 1 adult per 5 leaves in June. The incidence of disease, determined by crystalliferous live and dead mites, has ranged from 47% to 4%. Subeconomic mite levels have been maintained since mid-March.

Field experiments conducted at Orlando, Fla., again showed that zineb caused a buildup of Texas citrus mites. A positive correlation was shown to exist between zineb applications, decrease of Entomophthora sp., a fungus parasite of Texas citrus mites, and the increase in mite population. Reduction of Texas mites was obtained by fogging trees with water. The moisture apparently assisted the fungus parasite in becoming established.

An Entomophthora sp. fungus, parasitic in Texas citrus mite was found to have a 5- to 6-day life cycle under laboratory conditions at Lake Alfred, Fla. Death of mites occurred 4 to 5 days after infection. This fungus is prevalent in many groves and is believed to contribute materially to natural control of this mite.

Studies were continued under PL 480 Project A17-ENT-5 to determine the natural enemies of scale insects, fruit flies, and mites in West Pakistan. In 9 species of scale insects collected from a variety of plants, parasitism was moderately high, even in low density infestations. Parasitism of the California red scale was about 17%, the yellow scale 16%, and the olive scale 14%. An infestation of from 17 to 22 Tecaspis sp. scales per leaf on olive was controlled mainly by the lady beetle, Chilocorus infernalis, in August. Several new species of Anthocoridae were found predaceous on phytophagous mites.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Citrus Insects and Mites. Studies of the nature of a sex pheromone in the California red scale at Riverside, Calif., showed that males were attracted to exudates of crushed females on filter paper and females unattractive *in situ* became attractive when crushed. Crude extracts of whole virgin females crushed in numerous solvents were attractive to males. The solvents resulting in the most attractive extracts in descending order of male response were diethyl ether, acetone, chloroform, hexane, and methylene chloride. Attractiveness to the males was enhanced by exposing the extract on dummy females modeled with paraffin drops. In another method of extracting the sex pheromone, air drawn through an air-tight box containing approximately 10,000 virgin females on lemons into a cold trap, produced 325 ml of liquid in 20 days. This was extracted by mixing with diethyl ether and the ether reduced *in vacuo* at low temperature to 20 ml. Two µl aliquots of this concentrate placed on dummy females were as attractive to males as similar amounts of diethyl ether extracts of 50 crushed females.

2. Subtropical Fruit Flies. Aerial releases of sterile oriental fruit flies at the rate of about 1 million per week for 10 months in the 42-square mile area of Tinian and Aguijan in the Mariana Islands nearly eradicated the species there, but a persistent infestation of wild flies in high interior valleys on Saipan provided a source for reinfesting Tinian and surrounding areas on Saipan. During the same period, releases on Saipan (48 sq. mi.), at the rate of 2.5 to 3.5 million flies per week from 50 ground sites only, did not give adequate overflooding. Longevity of ground released flies was greatly reduced.

In late January the Hawaii station initiated a male annihilation program on Saipan, Tinian, and Aguijan (90 sq. mi.) to replace the sterile fly releases at a time when wild male oriental fruit fly catches were averaging about 100 flies/1000 trap days. A methyl eugenol-solution containing 3% naled (by volume) was used to saturate cane-fiber board squares 1"x1"x$\frac{1}{2}$" (later increased to 1$\frac{1}{2}$"x1$\frac{1}{2}$"x$\frac{1}{2}$"). Each square held from 5 to 15 grams of the lure, depending on size and composition of board. The squares were distributed at uniform intervals along flight lines (from 500 to 3500 ft. elevation depending on weather) 1/5 mile apart at a mean speed of 150 mph. In towns, similar squares were distributed by jeep. Applications were made at approximately 2-week intervals until 10 full and 2 partial applications had been made to Saipan and 8 to the other islands. Traps showed a substantial decline in fly catches with each generation. In the first month catches decreased to 50 flies per 1000 trap days. Catches of three successive generations declined to 7.4, 0.7, and 0.4 per 1000 trap days respectively. Since then none was caught. During the last two generations in April and May, a heavy crop of mangoes ripened and other preferred hosts were abundant. Despite favorable conditions no flies could be found on the extreme northern Mariana Islands. Cost of the 90-sq. mi. male annihilation program was 43¢ per acre for all materials and their application. Only about 3 wafers carrying a total of 35 grams of lure and 2 grams of poison were used per acre.

In Mexico a bait-chemosterilant combination was used in a 100 mango tree grove to control Mexican fruit flies, using one bait station for every two trees. Within 6 weeks 45% or more of the population was found to have taken up a green food dye that had been mixed with the tepa chemosterilant solution. Although the percent gravid females was not greatly reduced, compared to the control, the mango crop was protected for a period of four weeks during a period of high fly emergence.

F. Evaluation of Equipment for Insect Detection and Control

1. Subtropical Fruit Flies. A 30,000 curie, pool-type cobalt 60 unit was installed by the Atomic Energy Commission in January 1965, adjacent to the University of Hawaii's Food Science and Technology building. The unit will be used cooperatively by the University of Hawaii and the USDA for studies on disinfestation and shelf-life extension of Hawaiian fruits and vegetables. These studies will determine criteria for the possible design and installation of a semi-commercial unit, in the event practical quarantine treatments based on the use of radiation become available. Dose-distribution patterns in the 6"x16"x20" central canister and in the 3" tubes were determined by the Fricke dosimetric system. The dose rates were approximately 5 kilorads per minute in the canisters, used in the 3-tubes, on March 1, 1965. With this unit, 450 thousand fruit fly pupae can be irradiated at one time in about 2 minutes, compared to 1.5 hours in the old unit.

In Hawaii a low-cost trap made from a 1-gallon coffee can with plastic ends was equal to the standard Steiner trap in 14 weeks of testing. Five other designs of plastic traps with modifications in number, size, and position of openings gave catches ranging from 18 to 60% less than the standard.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantines

1. Subtropical Fruit Flies. In Hawaii 50° F was found to be the minimum effective temperature for ethylene dibromide fumigation of a 72% load of packaged papayas infested by the Mediterranean, melon, and oriental fruit flies when the dosage was 24 oz/1000 ft^3 for 2 hours and treatment was followed by an aeration period of 3 hours at 60° F and then by refrigeration at 40° F for 1 to 3 days. The egg and larval population estimated from pupae developing in untreated fruits was 152,000. No survivors were found after 24 oz/1000 ft^3 fumigation: (a) At 50° F followed by 24 hours of aeration and refrigeration at 40° F, (b) at 50° F followed by 3 or 24 hours of aeration and refrigeration at 50° F, (c) at 60° F followed by 3 or 24 hours of aeration and refrigeration at 48° F, (d) at 40° F followed by 24 hours of aeration and refrigeration at 40° F. There were two survivors in a population of 14,000 after treatment at 40° F followed by 3 hours of aeration and refrigeration for 3 days at 40° F. No survivors have occurred after treatment at 1 lb/1000 ft^3 for 2 hours at 70° F followed by 1 hour aeration at 70° F and refrigeration at 40° F. Limited data indicate that treatment with methyl bromide at 2 lbs/1000 ft^3 for $3\frac{1}{2}$ hours must be conducted above 50° F.

In Hawaii Dancy-type tangerines, packaged in cardboard orange cartons, were unaffected by fumigation treatments with EDB of 30-72% loads at doses of 24 or 48 oz/1000 ft^3 for 2 hours at 40-70° F following 6-7 days of refrigeration at 40-50° F. There was an increase of stem-end decay in navel oranges treated at 48 oz/1000 ft^3 and 40° F. Tangerines tolerated methyl bromide at 2 lbs/1000 ft^3 for $3\frac{1}{2}$ hours but navel oranges became pitted. Bluefield and apple bananas in ventilated wooden boxes were uninjured after treatment of 50-75% loads with EDB at 12 oz/1000 ft^3 for 2 hours at 70° F followed by 6 days of refrigeration at 55° F. However, the rate of coloring was accelerated by the treatment. Methyl bromide scalded the banana rinds at 2 lbs/1000 ft^3 for $3\frac{1}{2}$ hours at 70° F. Dancy-type tangerines were tolerant of hot-dip treatments of EDB in 100 gallons of water at 300 g for 5 minutes at 100° F, 170.3 g for 5 minutes at 115° F, 117.7 g for 10 minutes at 110° F, 106.0 g for 10 minutes at 115° F, 73.1 g for 15 minutes at 110° F, and 132.5 g for 20 minutes at 115° F.

In Hawaii 20-minute dip treatments of papaya at 115° F were ineffective at doses up to 54.8 g per 100 gallons of water (1:15,000 by volume) when the treated fruits were rapidly cooled to 65° F. No survivors were obtained at 109.5 g per 100 gallons (1:7,500), with rapid post treatment cooling.

In Hawaii the minimum dose of radiation required for disinfestation of fruits was found to be 21 kilorads for mature larvae of fruit flies and 76 kilorads for mango weevils extracted from the seeds. When packages containing fruit are treated, the doses must be corrected for attenuation, due to absorption by the fruit and packaging material. Refrigeration at 40° F before and/or after treatment reduced the formation of fruit fly puparia by approximately 93-98%. Weevils were moribund 0.4 to 1.3 months earlier than those not refrigerated. Ability to pack and chill fruit, as soon as picked, irrespective of time of application of the disinfestation treatment, will give the irradiation method another distinct advantage over fumigation or dip procedures.

In Hawaii poor flavor and aroma and severe scalding of the rind was found in Dancy-type tangerines when treated with 24-49 kilorads of gamma radiation at room temperatures and then refrigerated at 40° or 50° F for 4-7 days. Injury was avoided and only the increase in the rate of coloring was apparent when fruits were kept 4 days at room temperatures. Navel oranges were uninjured by post-treatment refrigeration after doses up to 49 kilorads. Apple bananas were uninjured by 24 kilorads. Bluefield bananas, probably because of less maturity, were scalded in the rind but the flavor and internal appearance were unaffected. Covering the bananas during growth did not improve the tolerance to post-treatment refrigeration.

2. Mango Weevil. The reproductive organs of adult weevils removed from seeds and irradiated at 10 and 15 kilorads in Hawaii recovered to normal size and functions 15 days later when compared to those in unirradiated weevils. Ovaries and testes exposed to 20-100 kilorads shrunk gradually with no sign of recovery.

3. Other Insects. At Hoboken, N. J., HCN fumigation at 1 pound per 1000 ft^3 for 2 hours under high, sustained vacuum near 70° F gave complete control of the methyl bromide-resistant Cecidomyid, Plemeliella abietina, and a seed chalcid, Megastigmus sp., found infesting spruce seed imported from Europe. HCN at 2 pounds for 2 hours without vacuum was also effective against Plemeliella but some Megastigmus survived. Four species of dry conifer seeds, including spruce, showed good tolerance to HCN as high as 2 pounds for 2 hours under vacuum. Carbon disulphide at 8 pounds for 24 hours also showed good insecticidal efficiency and seed tolerance. Ethylene oxide-carbon dioxide 10:90 mixture was effective against both insects at 25 pounds for 24 hours at normal air pressure but injured some conifer seed severely. Carbon tetrachloride at 58 pounds for 16 hours was found to injure a number of dry conifer seeds and its use on conifer seed is to be eliminated from the Plant Quarantine Treatment Manual.

At Hoboken, N. J., Japanese beetles entrapped in wheat were effectively controlled in small-scale tests by carbon tetrachloride-carbon disulphids 80-20 mixture (by volume, Vertifume) at a rate of 4 gallons per 1000 bushels for 4 hours or 3 gallons for 5 hours near 80° F. Complete kill also was obtained in a few tests at 4 gallons for 2, $2\frac{1}{2}$, or 3 hours. The carbon disulphide was found to aerate completely from the wheat within 24 hours but some carbon tetrachloride concentrations (above the maximum allowable) were still present after 72 hours aeration. The latter finding is important from a safety aspect.

H. Varietal Evaluation for Insect Control

1. Citrus Scale Insects. Surveys of Dancy tangerine plantings intermixed with orange and grapefruit at Orlando, Fla., showed that this variety is apparently resistant to attack by citrus snow scale. No infestations were found on the tangerine trees even though they were often surrounded by heavily infested orange or grapefruit trees. In many instances, rough lemon rootstocks on the tangerines were highly infested with a marked line of demarcation at the bud union.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Balock, J. W., and T. T. Kozuma. 1964. Notes on the biology and economic importance of the mango weevil, Sternochetus mangiferae (Fabricius), in Hawaii (Coleoptera: Curculionidae). Proc. Hawaii Entomol. Soc. 18: 353-64.

Estes, Z. E., and R. M. Faust. 1965. The nucleic-acid composition of a virus affecting the citrus red mite, Panonychus citri (McGregor). J. Invert. Pathol. 7: 259.

Mitchell, S., N. Tanaka, and L. F. Steiner. 1965. Methods of mass culturing melon flies and oriental and Mediterranean fruit flies. USDA ARS 33-104.

Tanaka, N. 1965. Artificial egging receptacles for three species of Tephritid flies. J. Econ. Entomol. 58: 177-8.

Biological Control

Clausen, C. P., D. W. Clancy, and Q. C. Chock. 1965. Biological control of the oriental fruit fly (Dacus dorsalis Hendel) and other fruit flies in Hawaii. USDA Tech. Bull. 1322. 102 pp.
Gilmore, J. E., and F. Munger. 1965. Influence of population density on the incidence of a noninclusion virus disease of the citrus red mite in the laboratory. J. Invert. Pathol. 7: 156-160.
Flitters, N. E., and P. S. Messenger. 1965. Effect of temperature and humidity on development and potential distribution of the Mexican fruit fly in the United States. USDA Tech. Bull. 1330. 36 pp.

Insect Sterility, Attractants, and Other New Approaches to Control

Steiner, L. F. 1965. A rapid method for identifying dye-marked fruit flies. J. Econ. Entomol. 58: 374-5.
Steiner, L. F., E. J. Harris, W. C. Mitchell, M. S. Fujimoto, and L. D. Christenson. 1965. Melon fly eradication by overflooding with sterile flies. J. Econ. Entomol. 58: 519-22.
Benschoter, C. A., and J. Telich C. 1964. Effect of gamma rays on immature stages of the Mexican fruit fly. J. Econ. Entomol. 57: 690.
Shaw, J. G., and M. Sanchez Riviello. 1965. Effectiveness of tepa-sterilized Mexican fruit flies released in mango grove. J. Econ. Entomol. 58: 26-8.

Insect Control Treatments for Commodities Regulated by Plant Quarantine

McPhail, M. 1964. Pad method of recovering fruit flies from infested fruit. J. Econ. Entomol. 57: 1012-13.

AREA NO. 5. FORAGE AND RANGE INSECTS

Problem. Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, seed chalcids, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Gulfport, Miss. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Research on clover and turf grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues is conducted at Beltsville, Md., and at Yakima, Wash., in cooperation with the Washington Experiment Station. Studies on varietal resistance, insect vectors of plant diseases and grass insects at

University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops), and S-55 (Alfalfa Insects).

Two contracts and 5 grants with State Universities and Agricultural Experiment Stations will provide additional research on insect biology, physiology, and nutrition, biological control, attractants and varietal resistance.

The Federal scientific effort devoted to research in this area totals 26.5 professional man-years. Of this number 5.0 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 4.0 to insecticide residue determinations, 4.6 to biological control, 0.6 to insect sterility, attractants, and other new approaches to control, 0.9 to evaluation of equipment for insect detection and control, 5.1 to varietal evaluation for insect resistance, 0.2 to insect vectors of diseases, and 1.1 to program leadership.

In addition Federal support of research in this area under contracts and grants provides a total of 1.9 professional man-years. Of this total 0.3 is devoted to basic biology, physiology and nutrition, 0.2 to biological control, 0.5 to insect attractants and other new methods of control and 0.6 to varietal evaluation of insect resistance.

A P. L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" is underway with the Research Institute of Plant Protection, Poznan, Poland.

PROGRAM OF THE STATE EXPERIMENT STATIONS

Studies on forage and range insects comprise an important part of the research program in the States. Populations of insects are being studied in relation to meadow composition, density, age, and crop sequence or type of range. Data on physical and biotic factors are recorded and analyzed to determine their relationships to insect abundance. Studies are being performed to determine the effects of environmental conditions on life cycles and pest insect physiology. Relationships between such factors as diapause and flight patterns to body fat content are under investigation. The mechanisms by which insects orient to their hosts are being determined by comparisons of the relative attractiveness of various odors, baits, flower and foliage colors, plant shapes and humidity gradients.

Chemical control research is being performed including the comparative effectiveness of materials, different application schedules, residue analyses and relationships to cultural controls such as crop rotation, fertilization and destruction of pest breeding sites.

Biological control research includes studies of the biology and ecology of predators, parasites, microorganisms with a view to increasing their effectiveness in reducing the abundance of pest insects or weeds. New biological agents are being introduced as quickly as their value is demonstrated.

In forage crops, studies are under way to develop plant varieties resistant to insect attack. Crosses of resistant and susceptible plants are being made to determine mechanisms of inheritance. Resistance found is being incorporated into agronomically desirable varieties. Research is also being performed on insect transmission of plant diseases.

The States' programs include 63.2 professional man-years of research on forage and range crops.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

1. Grasshoppers. Peak populations of the desert grasshopper (Trimerotropis pallidipennis pallidipennis) were higher in 1964 than in any year since 1959. Light damage to crops and desert vegetation was observed at several locations, and spring flights of the desert grasshopper were more frequent and in greater volume than in other recent years. The increase in population was apparently influenced mainly by favorable rainfall and desert vegetation conditions. However, the December population in 1964 was much lower than in 1963. The spring population in 1965 was drastically lower than in 1964, and much lower than expected in view of apparently favorable rainfall and vegetation conditions from mid-summer 1964 through the spring of 1965.

Grasshopper populations in rangeland habitats in Peeples Valley, Ariz., increased in 1964 following 3 successive years of population decline. Vegetation was more succulent and the vegetative cover slightly greater in 1964. Populations ranged from 1.15 per square yard in grass to 1.53 in Juncus meadow.

After 3 years of fairly stable and very low populations of grasshoppers, the grasshopper population in Arizona rose 194% in Conservation Reserve Land and 167% in 4 other habitats. Populations were highest in grassy and weedy field margins. Dissosteira carolina, Melanoplus sanguinipes, and M. packardii were the leading species.

In the spring of 1964 at Mesa, Ariz., adult females of M. sanguinipes developed from some of the eggs laid by unmated females in the fall of 1963. The eggs went through the usual winter diapause and hatched in May. The adults had deformed front wings and hind legs and none of them laid eggs.

At Mesa, Ariz., male-female ratios of 1:3, 1:1, 3:1 of M. sanguinipes adults were tested. As the ratio of males to females was increased, there was an increase in the longevity of females, the number of egg pods deposited, the

percentage of pods deposited normally below the soil surface, and the average number of pods deposited per female per day. The sex ratio apparently had no effect on the percent hatching or the number of eggs per pod.

Paired adults of M. sanguinipes maintained in 6 x 6 x 12-inch cages showed higher egg production, higher percent hatching, and greater longevity, at a density of 2 pairs per cage than at a density of 24 pairs per cage. When nymphs of this species were reared in cylindrical plastic cages 2-3/4 x 13 inches long, with screen ends, there was little difference in the percent of survival to the adult stage at densities of 2 numphs per cage and 12 nymphs per cage.

The body measurements of M. sanguinipes were greater for first-generation adults that were collected from dry rangeland in Arizona and reared in the insectary on a succulent diet than on adults of the same generation that completed their nymphal growth on the dry rangeland. Second-generation adults that were reared in the insectary on the favorable diet had larger body measurements than first-generation adults that received the favorable diet only during the latter part of the nymphal period.

On range recovery plots in Arizona the average grasshopper population on a sparse grass area for the period April-July 1964 in untreated fenced and grazed plots were 6.8 and 2.3 per square yard, respectively. By July 16, the percentages of grass eaten by one grasshopper per square yard in the fenced plot, with a grass cover of 7.7%, were 5.5 on blue grama, 4.6 on curly mesquite, and 14.1 on squirreltail. In October the percentage of grass cover was 15.5%, and in the fenced plot, it was 7.9% higher than in 1963.

At Bozeman, Mont., several species of range grasshoppers have been colonized in the laboratory, so they will be available for parasite and disease research. Schistocerca americana, brought in from Tennessee, is being reared successfully. Colonies of S. vaga vaga are being maintained for research on the adult diapause found in this species.

2. Alfalfa Insects. At Beltsville, Md., a non-diapausing colony of the alfalfa weevil was maintained in the laboratory under 8-10 hour day-length conditions for the third year. During 1964 six generations were completed. The effect of day lengths of around 18 hours of light, that normally yield diapausing weevils, was overridden by inserting a one hour dark period in the center. Larvae collected in the field during the spring and summer produced diapausing adults, while those collected in late fall produced non-diapausing adults.

Ninety-five modifications of an artificial larval diet capable of producing normal alfalfa weevil adults but less satisfactory than fresh alfalfa were tested at Beltsville with little improvement in survival and time required for development.

Previous cross mating tests between eastern and western strains of the alfalfa weevil demonstrated that they differ genetically and are partially isolated reproductively. Further tests during 1964-65 showed that when allowed free choice, males and females of both strains mated indiscriminately, egg hatch was reduced about 25%, and there was a slight increase in percentage of female progeny. When eastern and western males were placed with eastern females they competed equally as mates, egg hatch was reduced about 70%, and the sex ratio of progeny was equal. Eastern females confined with western males again produced only infertile eggs.

At Tucson, Ariz., an effort to break the adult diapause in the Egyptian alfalfa weevil, Hypera brunneipennis, was successful. A lot of eggs was incubated at room temperature, and the larvae obtained were grown to maturity on potted plants in a chamber in which 8 hours of light were provided each day. Seventy-three F_1 adults emerged between May 20 and June 9. These were caged on potted alfalfa plants in the chamber under an 8-hour day. First eggs from these adults were recovered on June 28, 39 days after the first F_1 adults emerged.

In the fall of 1964 sexuales of the spotted alfalfa aphid, Therioaphis maculata, continued to spread into States adjacent to Nebraska. These forms are now found in Iowa and Wyoming. This, plus the fact that an apparently separate occurrence of a holocyclic strain was found in Wisconsin, indicates that overwintering as an egg in the northern United States may become the rule rather than an exception for this species.

At Mesa, Ariz., studies were made on the life history and behavior of Aceratagallia curvata and Acinopterus angulatus under greenhouse conditions. Both of these leafhoppers are important pests of alfalfa in Arizona and vectors of important virus diseases. The life cycle of both species is less than 40 days and they are capable of producing several generations a year exclusively on alfalfa.

3. Clover Insects. At Lincoln, Nebr., pea aphids, Acyrthosiphon pisum, taken from sweetclover in the fall of 1963 and reared in the greenhouse reproduced and survived decidedly better on sweetclover than on alfalfa. A culture of these aphids was established, after some difficulty, on alfalfa and the resulting generations survived equally well on alfalfa or sweetclover. During the fall of 1964 pea aphids were taken from alfalfa and sweetclover in the field and reared on their respective hosts in the greenhouse. Reproduction and survival were better when the aphids were transferred to the same species of host, upon which they had been reared. This may indicate the development of a biotype with host preference.

4. Grass Insects. Observations were made at Lincoln, Nebr., on a midge (Cecidomyidae) which destroys the developing caryopses of smooth bromegrass. It appears that there may be two generations during the short time before the caryopses begin to mature. Pupation apparently occurs within the flume at the site of the destroyed caryopses. All stages of a parasite (Eulophidae) were

found in association with the midge with the percentage of parasitism quite high. Unfortunately, the damage has been done by the time the parasite destroys the midge.

At University Park, Pa., weekly sweep-net collections in a stand of timothy and one of bromegrass during the spring and summer of 1964 showed virtually the same major insects in each. These included the plantbugs Trigonotylus ruficornis and Lygus lineolaris; the leafhoppers Endria inimica, Graminella nigrifrons, Macrosteles fascifrons, Latalus sayi, Aceratagallia sanguinolenta; the fulgorid, Delphacodes campestris, the meadow spittlebug, Philaenus spumarius, and the pea aphid Acyrthosiphon pisum. The major diptera comprised a complex of the genus Oscinella.

At Tifton, Ga., the spittlebug, Prosapia bicincta, that attacks and severely damages Coastal bermudagrass, has been successfully reared from egg to adult. Eggs were placed on millet sprouts, and newly emerged nymphs fed on the roots for 4-7 days after which they were transferred to Coastal bermudagrass in 4-inch pots in a greenhouse. From 50 to 80% of the nymphs survived transfer, established themselves on the roots, and made new spittle masses. The cycle from eggs to adults required 40-59 days.

A study was made to determine how the spittlebug damages Coastal bermudagrass. Adults were caged on single stems in 4-inch pots. An adult spittlebug was confined to single stems of Coastal bermudagrass for 1, 2, 4, 8, 16, 24, 48, 96, and 168 hours and the plants were observed for 2 weeks. Damage symptoms began to appear in 3 days and consisted of a yellow stippling of the leaves and sheaths. The stippled areas coalesced to form streaked areas at about 5-7 days. After 7-10 days the leaves turned brown and dried up. The number of leaves which showed symptoms and the severity of the damage was in direct proportion to the length of time the adults fed. When adults were confined to stems below the attachment of the first leaf sheaths, symptoms appeared in the leaves above and in the growing tip. When adults were confined on one branch of a forked stem, symptoms appeared only on the branch on which the insect fed. Observations indicated that the adults introduce a toxin into the vascular tissue that destroys the chlorophyll. Nymphal feeding did not cause similar symptoms. Stems fed upon by 4th instar nymphs had small dark brown lesions near the soil level. The lesions were strictly local because xylem and phloem appeared normal a few microns above the lesion. It is thought that the nymphs kill the cells in the immediate vicinity of the feeding site and that if a toxin is secreted it is not translocated.

Spittlebug eggs entered diapause when held at 80° F constant temperature and in water-saturated filter paper in plastic petri dishes. Photoperiods of 14 and 16 hours per day did not prevent diapause of newly laid eggs. However, allowing the filter paper and attached eggs to air dry one day, prevented diapause. Chemicals were found to break diapause. Best results were obtained with a 30-second dip in laundry bleach. Incubation of diapausing eggs at 100° F for 7 days and at 48° F for 7 and 14 days was 30-35% successful in breaking diapause.

At Tifton, Ga., spittlebug adults were taken in fluorescent light traps in large numbers. The traps ranged from 6 to 90 inches in height above ground. The proportion of females captured was less than 5% in the highest traps but increased as the height of the traps decreased. Sexes were about equal in traps 6 inches high located in a heavily infested area. Traps, even of the low type, nearest the periphery of an infestation caught less than 20% females. These observations indicate that adults migrate from heavily damaged areas and that the males move faster, or perhaps farther than the females. The gravidity of the female population as determined through dissection of 700 specimens, was not correlated with the proportion of females caught in relation to the height of the traps.

A study of overwintering bermudagrass sod reserves indicated that losses due to spittlebug damage in the fall is carried over into the spring with reduced yields of forage. The ability of Coastal bermudagrass to recover from severe damage also was demonstrated.

At Mesa, Ariz., two species of leafhoppers, Carneocephala nuda and C. triguttata, were successfully crossbred in captivity. Both species are important pests of bermudagrass. C. triguttata is a vector of Pierce's disease virus of grapes or alfalfa dwarf virus. All intraspecific, interspecific, and reciprocal crosses produced progeny in the F_1 generation.

At Forest Grove, Oreg., studies on several species of sod webworms indicate that Crambus topiarius is the principal economic species. In some years it has been very injurious in old plantings of Merion bluegrass. While it is prevalent in other varieties of bluegrass, as well as in the fescues and bentgrasses, it has done much less obvious damage to these grasses. The larvae feed both upon the grass blades and upon the root system, but the root feeding causes the most damage. C. bonifatellus, while usually scarce or entirely absent in commercial grass plantings, is common on lawns. Larval damage to the sod is usually not evident, possibly because bonifatellus prefers lawns that have been adequately fertilized and watered; hence the sod may be able to recoup damage losses as fast as they occur.

C. bonifatellus proved to be one of the most adaptable of the crambid species for rearing from egg to adult in the laboratory. C. dorsipunctellus is one of the most common species on open bunch grass rangelands and in fescue seed producing areas but its rank of economic importance is not yet established. C. leachellis and C. tutillus are two species that are occasionally abundant in certain very restricted areas. C. leachellis occurs in bent and mixed wild grasses in the rainy seacoast area as well as inland areas up to 2000 feet elevation in central Oregon. C. tutillus moths were found only in very limited areas and chiefly in the short fescues. No larval damage was noted that was caused by this species.

5. White-fringed Beetles. White-fringed beetle larvae Graphognathus peregrinus, severely damaged new plantings of pine seedlings in Mississippi, in January and February 1965. The seeds, planted in December 1964, were

treated with endrin as a bird repellant, which apparently did not affect the larvae. Seedlings were cut off just below the surface of the ground when they were approximately one inch in height. This indicates that these larvae can feed and cause economic damage during the winter.

During the spring of 1965, larvae of G. peregrinus severely damaged a field of sugarcane near Grand Bay, Ala. The principle damage was caused by the larvae feeding on the eyes or buds as they grew from the seed pieces thereby greatly reducing the stand. Over the entire field, stand reduction was estimated at 30% but was as high as 90% in certain parts of the field.

A grant was recently awarded to Auburn University to develop artificial rearing techniques for the white-fringed beetles, and research is being initiated.

B. Insecticidal and Cultural Control

1. Grasshoppers. Small plot tests were conducted at Bozeman, Mont., to compare low-volume applications of several insecticides with an aldrin standard against rangeland grasshoppers. Undiluted MCA-600 at 4 and 6 ounces per acre (spray volume 2 and 3 pints per acre, respectively) and undiluted carbaryl concentrate at 4, 6, and 8 ounces per acre actual (spray volume 1, 1-1/2, and 3 pints per acre, respectively) approached but did not equal the standard in effectiveness. Naled diluted with light, cracked gas oil at 6 and 8 ounces per acre actual (spray volume 1-1/2 and 2 pints per acre, respectively) also approached but did not equal aldrin. Diazinon in post treating oil at 8 ounces per acre actual (spray volume 2 pints per acre) was more effective than the standard. American Cyanamid EI-47772 at 2 ounces per acre actual in post treating oil (spray volume 2 pints per acre) was well below the standard in this test.

Laboratory screening tests were conducted with 30 insecticides against adults of the migratory grasshopper, M. sanguinipes. Acetone solutions of the insecticides were applied topically at 2.10 and 10.50 µg per insect. Only two compounds NIA 10242 and Dursban compared favorably with aldrin.

Several insecticides were applied by aircraft at ultra-low volumes. Bidrin at spray volumes of 7.4 and 8.4 ounces (0.93 and 2.10 ounces active material) per acre, gave satisfactory control. Application of 5.6 to 11 ounces of active naled per acre gave mortalities ranging from 87.7 to 97.7%. Satisfactory control was obtained with diazinon at 8 to 10 ounces of active material per acre. Carbaryl in the formulation tested was too volatile; crystals formed in the spraying system and dosages were questionable. Bayer 25141 gave very good control at dosages of approximately 1 and 3 ounces per acre.

2. Alfalfa Insects. At Beltsville, Md., fall 1964 and early spring 1965 applications of commercial and experimental insecticides failed to give adequate control of the alfalfa weevil on first crop alfalfa. Thirteen experimental insecticides applied to the growing crop in the spring of 1965

gave weevil control equal to or better than methoxychlor at 24 ounces.

During the winter 38 new materials were screened in the laboratory against adult alfalfa weevils. Those showing most activity in residual tests were Bayer 39007, GC 6506, Hercules 14504, and Velsicol FCS-13. Materials showing a high degree of systemic action were: GC 3707, GC 6506, Stauffer R-7239, R-7240, and B-10288, Velsicol FCS-13, and OCS-21959, VC-3-668, and VC-9-104.

At Lincoln, Nebr., insect populations in alfalfa were generally low and adverse climatic factors were not favorable for good seed set. Plant bugs and alfalfa seed chalcids, both of which directly affect seed production, were present. Six insecticides applied in the prebloom stage were equally effective initially against the plant bugs but none equalled DDT in producing a lasting effect. None of the insecticides were effective against the alfalfa seed chalcid.

In three tests during 1964 and the first half of 1965 baits containing mirex in soybean oil impregnated in corncob grits showed little promise for control of the red harvester ant, Pogonomyrmex barbatus, in irrigated alfalfa fields near Mesa, Ariz. In some of the test series, the ant colonies had been treated for more than a year at the last inspection in the spring of 1965.

3. Grass Insects. At Tifton, Ga., several insecticides were tested during the summer of 1964 to control the spittlebug, Prosapia bicincta on Coastal bermudagrass. Granular lindane was superior to all other insecticides tested for control of nymphs and adults. Sprays of Bidrin and MCA-600, at 1.0 pound per acre were effective in reducing populations of nymphs while sprays of Imidan and Bomyl, at 1.0 pound per acre were not. Bomyl and diazinon granules, both at 1.0 pound per acre, showed promise.

At Tifton, Ga., insecticides were applied to Coastal bermudagrass to control several phytophagous insects including the fall armyworm, and a composite of leafhopper species. An increased yield of grass forage was obtained with sprays of MCA-600, Bomyl, and Bidrin at 0.5 pound per acre. Endosulfan, carbaryl, diazinon, and Imidan were effective in reducing the insect complex but no increased yield of forage was measured in these treatments.

At Tifton, Ga., the insecticide GC 3707 was applied to Coastal bermudagrass, silage corn, and millet in sprays at rates of 4 and 8 ounces per acre. Samples of foliage were taken to the laboratory and fed to 4-day-old fall armyworm larvae. Mortality counts were made at 24 and 48 hours. The 8-ounce rate gave immediate control of 98% on corn, 84% on bermudagrass, and none on millet. The 4-ounce rate gave 43% immediate control on corn and poor control on the other crops. Samples taken 1 day after treatment showed only negligible control with both rates on the 3 crops.

4. White-fringed Beetles. At Gulfport, Miss., overwintering larvae of G. peregrinus were placed in soil containing extremely high concentrations of dieldrin and Telodrin to determine if it would be feasible to control larvae

damaging new plantings of pine seedlings in January and February. No mortality occurred when these larvae were placed in soil containing 250 pounds of actual dieldrin per acre and 2000 pounds gave only 40% mortality. Telodrin at 250 pounds per acre gave only 60% control and 1000 pounds were necessary to give 100% control.

C. Insecticide Residue Determinations

1. MCA-600 Residues on Silage Corn. At Tifton, Ga., MCA-600 was applied to corn at 8 ounces per acre in a spray. Analysis of samples of corn taken the day of treatment and at intervals of 1, 2, 4, 7, 14, 21, and 28 days showed residues on a green weight basis of 7.46, 6.40, 2.85, 1.21, 0.53, 0.16, <0.10, and <0.10 ppm, respectively.

2. Bidrin Residues on Silage Corn. At Tifton, Ga., Bidrin was applied to corn at the rate of 4 ounces per acre in a spray. Samples of corn were taken the day of treatment and at intervals of 1, 2, 4, 7, 14, and 21 days were analyzed at Beltsville, Md., and the residues on a green weight basis were, respectively, 6.32, 1.52, 0.64, 0.46, 0.18, and 0.10 ppm. The minimum sensitivity of the analytical methods was 0.1 ppm.

3. Imidan Residues. Standing corn was sprayed with Imidan at 4, 8, and 16 ounces per acre, harvested 24 hours later, chopped and packed in gallon jars. Samples of the chopped corn were analyzed for residues and after 59 days the jar silage was analyzed for Imidan residues. The residues found were as follows: 4 ounce per acre chopped corn 2.36 ppm and silage 1.06 ppm, 8 ounces per acre chopped corn 5.32 ppm and silage 1.77 ppm, 16 ounces per acre chopped corn 14.72 ppm and silage 4.97 ppm. The loss of Imidan in the 59-day storage period ranged from 55 to 67%.

Standing corn grown for ensiling was treated with Imidan spray at 4, 8, and 16 ounces per acre, and sampled immediately after treatment and at intervals of 1, 2, 4, and 7 days. The samples were analyzed by the total phosphorous method. Residues in ppm at the above stated intervals were as follows: 4 ounces per acre, 9.23, 2.36, 1.69, and 1.36, (the 7th day sample was lost); 8 ounces per acre, 15.57, 5.32, 4.79, 3.82, and 2.30; 16 ounces per acre, 17.16, 14.72, 13.67, 10.67, and 7.20.

At Tifton, Ga., Imidan was applied to silage corn at 8, 16, and 32 ounces per acre as an emulsion spray. The plants were sampled as soon as the spray was dry, and one day after treatments. The initial residues obtained with the 8, 16, and 32 ounce treatments were 6.80, 11.36, and 30.0 ppm, respectively, and one day after treatment, when the corn was ensiled, the residues were, respectively, 3.43, 9.72, and 20.4 ppm. During approximately one month's storage these residues degraded to 1.56, 6.27, and 10.02 ppm. The silage was fed dairy cows for 50-56 days after the month's storage and during the feeding period silage samples composited weekly averaged 1.10, 3.42, and 6.88 ppm, for the 8, 16, and 32 ounce treatment, respectively. Milk samples were analyzed by gas liquid chromatography using an electron affinity detector.

No residue was found in excess of the minimum sensivity of the analytical method. Whole blood samples taken from the cows at weekly intervals showed no evidence of cholinesterace inhibition in animals fed corn silage treated at rates of .5 or 1 pound per acre. There was evidence of a minor (less than 20%) inhibition of cholinesterace in animals fed the 32 ounce treatment for a period of 56 days.

4. Dimethoate Residues in Silage. At Beltsville, Md., samples of alfalfa that had been sprayed with dimethoate were collected before ensiling and at intervals afterwards. Samples collected before ensiling contained from 81.6 to 95.8 ppm of dimethoate. The residues in silage samples decreased as the experiment progressed, falling from an average of 41.7 ppm to 25 ppm over a period of 2 to 2-1/2 months.

5. Phosphate Insecticide Residues on Alfalfa. Samples of alfalfa at Beltsville, Md., were analyzed from plots that had been treated with 1 pound of Imidan, 1 or 0.25 pound of Bayer 25141, or GC 3707 at an unstated dosage. The samples were taken 35 days after treatment. No residues of GC 3707 were detected in excess of the sensitivity of the analytical method (0.06 ppm). Residues of Bayer 25141 averaged 0.47 ppm from the 1-pound per acre plot and 0.16 ppm from the 0.25-pound plot. A residue of 0.16 ppm of Imidan was found in the alfalfa treated with that insecticide.

6. Heptachlor Residues. At Beltsville, Md., samples of soil and alfalfa were taken in the spring of 1964 before the first cutting of alfalfa from alfalfa fields that had been commercially treated with heptachlor in the fall of 1963. Analysis of the samples showed the presence of 0.16 to 0.25 ppm of heptachlor epoxide in the alfalfa from treated fields. The soil samples contained heptachlor residues ranging from 0.033 to 0.018 ppm and heptachlor epoxide residues from 0.004 to 0.085 ppm.

In translocation studies at Beltsville, Md., alfalfa plants were grown in porcelain pots in soil treated with heptachlor or heptachlor epoxide at rates of 1 or 4 pounds per acre. Three cuttings of the foliage were made and samples were analyzed for heptachlor and heptachlor epoxide. Results indicated that there was no translocation of heptachlor or heptachlor epoxide into the aerial parts of the alfalfa plant in amounts detectable by the method of analysis employed (minimum level 0.01 ppm).

7. Bayer 25141 Residues in Range Grass. Bayer 25141 was applied to range grass at the rate of 1, 2, or 3 ounces of active ingredient per acre. Samples of the range grass taken 0, 7, and 44 days after application and analyzed at Yakima, Wash., showed residues of 29.8, 19.4, and 4.6 ppm from the 1-ounce dosage, 54.0, 42.0, and 12.3 from the 2-ounce dosage, and 64.6, 53.9, and 19.2 ppm from the 3-ounce dosage.

8. MCA-600 Residues on Range Grass. Samples of range grass were taken before and at intervals after treatment with 2 or 4 ounces of undiluted MCA-600 per acre. Residues found at 0, 7, 14, and 28 days after application

were 37.8, 21.4, 12.0, and 2.4 ppm for the 2-ounce application and 58.8, 52.1, 35.6, and 7.9 ppm for the 4-ounce application.

9. Phorate Residues on Lupine. At Tifton, Ga., biological assay indicated that there were residues of phorate in seeds of yellow and blue lupine harvested from fields treated with a granular formulation. Granular phorate is used to control aphids thus reducing the incidence of Bean Yellow Mosaic Virus and increasing seed production.

D. Biological Control

1. Grasshoppers. In 1964 natural enemies, mostly birds and dipterous larval parasites, were abundant and destroyed many grasshoppers in limited areas in Arizona. In June, on the San Carlos Apache Indian Reservation, parasitism of adult grasshoppers by larva of flesh flies was 2.9% and ranged up to 9.0%. In mid-October, in a small area bordered by oak trees, adults of Trachyrhachys mexicana and Arphia p. crassa were parasitized 66.6 and 57.1%, respectively, by larvae of Trichopsidea clausa. By mid-September on rangeland in extreme southern Arizona adults of Morseilla flaviventris and Boopedon nubilum grasshoppers were parasitized 60 and 36%, respectively. There were very few mite-infested grasshoppers on rangelands in southeastern Arizona.

At Columbia, Mo., studies on the red grasshopper mite, Eutrombidium trigonum revealed a method of sperm transfer involving the production of spermatophores. The spermatophores consist of an orange-colored capsule attached to the apical portion of a thin, translucent, whitish stalk whose base is embedded in the substratum. The capsule enclosed a homogeneous mass of granular material. No active sperm were observed in the capsules examined. The spermatrophore stalk from the base to the branch supporting the sperm capsule averaged 318 microns in length. The diameter of the capsule averaged about 75 microns. After deposition of the spermatophore the male mites invariably performed a nuptial dance before resuming their previous exploratory or feeding behavior. This is the first instance in which the production of spermatophores by male mites has been found in this genus, although other members of the family Trombidiidae have been known to produce spermatophores.

During the 1964 season field applications of spores of the protozoan, Nosema locustae were made in 9 locations in northwestern Montana. Except for one site, the spores were applied in a localized area, generally no larger than 100 square feet. Two months after application infection rates at these 9 sites ranged from 10 to 50% at the application points. The percent of infection was less at points away from the area where the spores were applied. No significant infections were found in untreated control sites. From this it was determined that it may be feasible to apply Nosema spores under field conditions.

The field study for observing the disease under natural conditions is being continued in Camas County, Idaho. During 1964, more than 4% of the grasshoppers examined were infected with detectable levels of Nosema spores. This

level approximates that observed during 1963; however, since grasshopper population levels were considerably higher during 1964 the actual number of infected specimens was double that of 1963. At four of the plot locations the average infection during September was in excess of 50% and as high as 100% at one location.

2. Alfalfa Weevil. In 1965, the alfalfa weevil continued to spread in Arkansas, Missouri, Illinois, Indiana, Ohio, and Vermont. Releases of parasites were continued in Vermont, New York, Massachusetts, Delaware, Pennsylvania, Ohio, Indiana, Illinois, Missouri, and Virginia. Releases included Bathyplectes curculionis, B. anurus, Tetrastichus insertus, and Microctonus aethiops. All of these are established and spreading at one or more locations. Parasitism by T. insertus at the 1962 release site in Massachusetts was 64% in the spring of 1965. Parasitism by B. curculionis at at a Massachusetts release site was 44%. Parasitism at release sites in Pennsylvania, Maryland, and Virginia was less than 5%. Some build-up and spread of these two parasites are indicated.

A study was begun in the spring of 1963 to determine the amount and effect of parasitism on the alfalfa weevil in an area immediately east of the Rocky Mountains which includes the eastern parts of Colorado and Wyoming and the western portions of Kansas, Nebraska, and South Dakota. The weevil is not as damaging in this area, nor is it spreading nearly as fast as it is in the Eastern States. Parasitism by B. curculionis ranged from 8% to 65% in 1963, and from 13 to 96% in 1964.

3. Egyptian Alfalfa Weevil. Two parasites of the Egyptian alfalfa weevil, Hypera brunneipennis, were released in alfalfa fields near Mesa, Ariz., during March and April 1965. A total of 567 adults of Tetrastichus incertus, a larval parasite, was released March 9, and 743 larvae of Microctonus aethiops, an adult parasite were released March 18 and April 7. In connection with the parasite releases, seasonal abundance counts of H. brunneipennis larvae were made. Larvae were collected each week from February 2 to May 26. Peak populations averaging about 600 larvae per 100 sweeps were recorded March 23 and 30.

4. Spotted Alfalfa Aphid. Surveys in 1964 showed that Trioxys utilis was widely distributed in central and southern Arizona and southwestern New Mexico. No other parasite species were recovered. Of all aphids examined only 1.7% were parasitized and the highest in any field was 8%.

Observations throughout 1964 in four alfalfa fields near Mesa, Ariz., showed that the leading predators were Orius spp., Collops vittatus, and nabids. The total number of predators decreased 27% compared with 1963. The lady beetle population was very low until mid-March. Then it increased sharply to a peak in mid-April which coincided with the peak of the spotted alfalfa aphid. No aphid mortality from fungus diseases was observed in the four fields. Average parasitization by T. utilis increased slightly, from 8.54% in 1963 to 9.91% in 1964. Populations of spotted alfalfa aphids, lady beetles, and total predators were 65.4, 77.5, and 49.6% lower, respectively, than for the 6-year period 1958-63.

The decrease in lady beetle populations in Arizona for the 10 years, 1955-64, has coincided with a decrease in the spotted alfalfa aphid population. During the spring of 1965 the percentage of aphids parasitized by T. utilis averaged 21.9% compared to 10.0 in 1964.

5. Armyworms and Cutworms. At Baton Rouge, La., parasitism of the fall armyworm averaged about 40%, which is lower than previously recorded in these studies. Disease was non-existent in the collections.

6. Rhodesgrass Scale. In June 1965 a contract was awarded to Texas Agricultural Experiment Station, at Weslaco, Tex., to investigate means of mass producing and distributing Neodusmetia sangwani, an effective parasite of the Rhodesgrass scale.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Spittlebugs. Females of the spittlebug, Prosapia bicincta, give off a strong vanilla-like odor during the first week of adult life. At Tifton, Ga., experiments were conducted to determine if the odor was a sex attractant. Virgin females were confined in one branch of a Y tube with Coastal bermudagrass as food. The other branch contained only Coastal bermudagrass. Field collected males were introduced at the base of the Y. A fan pulled air toward the base of the Y. Tests with females 1 through 8 days of age resulted in more males being collected in the food branch than the female branch of the Y.

2. Alfalfa Weevil. At Beltsville, Md., laboratory and field tests with liquid propane flamers demonstrated that applications of heat to established alfalfa fields in the spring before growth begins effectively controlled the alfalfa weevil without damage to the crop. Weevil eggs in stubble were more susceptible than adult weevils. Some weed control was also obtained. A new alfalfa seeding, however, was severely damaged by all levels of heat application.

Research is being initiated at Blacksburg, Va., under a grant awarded in June 1965 to Virginia Polytechnic Institute to investigate attractants and stimulants for the alfalfa weevil.

3. Alfalfa Seed Chalcid. In June 1965 a grant was awarded to the University of Wyoming to study the ovipositional behavior of the alfalfa seed chalcid to chemicals occurring in alfalfa.

F. Evaluation of Equipment for Insect Detection and Control.

1. Grasshoppers. At Bozeman, Mont., a miniature spinning cage atomizer, developed by the Plant Pest Control Division, and popularly known as the Mini-spin, was compared with standard boom and nozzle spray gear in tests for control of grasshoppers on rangeland. Forty-acre plots were treated with aircraft using undiluted technical malathion. The best control was obtained when treatment was made with the Mini-spin nozzle, but the differences did not prove statistically significant. Spray patterns taken on dye-cards showed the

best control of droplet size to be from the Mini-spin. The ultra-low volumes applied per acre were believed largely responsible for greater variation in the mortalities than usually found in similar field tests with larger volumes of spray material.

2. Alfalfa Weevil. An experimental field applicator was designed at Beltsville to deliver technical liquid insecticides in aerosol form in amounts as low as 4 ounces per acre. This was mounted on a tractor and the aerosol disbursed under a trailing plastic canopy. In field tests the aerosol application did not equal conventional spray applications for alfalfa weevil control. The canopy allowed some of the aerosol to escape.

G. Varietal Evaluation for Insect Resistance.

1. Potato leafhopper. A field evaluation was made at Lincoln, Nebr., on 75 alfalfa clones for resistance to the potato leafhopper, Empoasca fabae. Visual ratings were based on an estimate of the percent of leaf tissue which showed feeding injury. In general, higher leafhopper populations occurred on the more heavily damaged plants; however, equal numbers of leafhoppers did not cause the same degree of injury to all clones. Certain resistant clones appeared to be unattractive to leafhoppers; others appeared to be tolerant. Correlations between visual ratings and population density, as measured by nymphs per gram of plant material, were all significant at the 1% level.

At University Park, Pa., a detailed comparison of selected leafhopper-injured and sprayed alfalfa clones planted in pairs in a space nursery showed that in addition to yellowing, damaged plants were shorter, had a higher percent of dry matter, shorter middle and top internodes, and more branching than protected plants. The kinds of injury are being explored for possible use in measuring antibiosis reactions of alfalfa strains to potato leafhoppers.

The potato leafhopper is not considered to be a pest of sweetclover, but in 1964, certain experimental lines in a nursery at Lincoln, Nebr., showed considerable injury by this insect. Of the recommended varieties present, Denta showed no visual injury and injury to the others was light. There was a positive correlation between leafhopper populations and injury ratings. In a subsequent greenhouse test leafhopper reproductive rates were significantly higher on one of the entries that showed damage in the field than on two others which showed little or no damage. While all the recommended varieties had some degree of resistance, it should be noted that there are lines which do not have resistance. This may be important because the use of other characters from these lines could result in the transfer of leafhopper susceptibility to improved varieties.

2. Alfalfa Weevil. Improvements were made at Beltsville, Md., in laboratory testing techniques for the alfalfa weevil. Placing cut stems in flats of sand rather than in individual water vials reduced materially the time required for setting up test material for oviposition and feeding response. The preparation of material for larval survival tests was also reduced by placing cut stems in

agar slants in glass tubes. The use of seedling plants in adult feeding preference tests was found to be a promising method of rapid selection. Significant differences were found among alfalfa entries in terms of egg laying, adult visitations to stems, adult feeding on stems and seedlings, and larval survival.

3. Egyptian Alfalfa Weevil. From 18 alfalfas planted in rows at Yuma, Ariz., in 1963, 71 plants were selected for possible resistance to larval feeding of H. brunneipennis. Selection was made on the basis of superior growth and light feeding marks during a period of severe damage to the planting as a whole. Eighteen of the plants were selected after new-generation adults had fed heavily for several weeks, their superior condition indicating possible resistance to adult feeding as well.

At Mesa, Ariz., about 1000 plants were visually rated in field plots for resistance to this insect. After two years of field evaluation only 16 plants were selected which appeared to be free of damage.

4. Spotted Alfalfa Aphid. At Tucson, Ariz., 442 Sonora and Moapa clones selected for possible resistance to alfalfa mosaic on the basis of tall stems and healthy roots were given stem-cage tests to determine level of resistance to spotted alfalfa aphid. The testing was performed in cool weather of winter and early spring to permit isolation of the clones with resistance that would hold up the year round. Forty-five clones were classified as highly resistant.

Twenty-eight clones selected at Mesa, Ariz., for resistance to the alfalfa seed chalcid were tested for resistance to two biotypes of the spotted alfalfa aphid. Sixteen were classified as highly resistant to both biotypes and two as susceptible to both. Most of the others were highly resistant to biotype ENT B but had lower or no resistance to ENT A.

Thirty-eight clones from the Nevada breeding program selected for good performance in a root disease plot at Mesa were tested for resistance to the spotted alfalfa aphid. Twenty-three were highly resistant to both biotypes.

Eighteen experimental and commercial alfalfa varieties were screened in the greenhouse for plants resistant to the spotted alfalfa aphid in the seedling stage. Four hundred and twenty-seven clones were selected from 48 flats of material. These were given stem-cage tests after being transplanted to the field and 292 were found to be highly resistant to both biotypes.

In greenhouse studies at Lincoln, Nebr., plants resistant to the spotted alfalfa aphid, Therioaphis maculata, that received a low level of Ca or a high level of N had a significantly higher number of live aphids after 4 days in comparison to resistant plants that received medium or high levels of Ca or low and medium levels of N. Nymphs produced and maintained on the terminal ends of low Ca resistant plants and high N resistant plants grew to maturity and reproduced. Susceptibility was not altered by any of the N or Ca levels. None of the other treatments (K, P, S, and Mg.) altered survival or reproduction of the aphids on resistant or susceptible plants.

At Manhattan, Kans., progress is being made under contract with the Kansas Agricultural Experiment Station in developing alfalfa varieties with combined resistance to two or more insects. Out of 187 plants from the synthetic variety KS10, 23 were resistant to the spotted alfalfa aphid, pea aphid, and bacterial wilt.

In connection with the above contract, studies were made on nymphal and adult survival of the spotted alfalfa aphid on excised and intact trifoliolates. Excised plant parts are frequently used in screening for resistance, particularly antibiosis. Of 50 clones tested, 24% showed significant differences in adult survival and 20% in nymphal survival comparisons. In all cases where the differences were significant, the survival on excised trifoliolates exceeded that of the intact trifoliolates of the same clone. These results indicate that using excised trifoliolates with the spotted alfalfa aphid might tend to underestimate the resistance level and make a clone appear somewhat more susceptible.

5. Pea Aphid. Seventy-eight Arizona clones resistant to root rots and the spotted alfalfa aphid were tested for resistance to the pea aphid. Eight clones derived from African and 10 derived from Lahontan were found to have a useful level of antibiosis.

Eighty winter-tender clones selected for good performance against pea aphid in a large cage at Logandale, Nev., were given several tests in stem-cages at Tucson, Ariz., to isolate the clones with the highest antibiosis to this insect. Thirty-eight were selected for further study.

At Poznan, Poland, under a P. L. 480 project, two Nevada selections of alfalfa, Medicago sativa, (Nev. 416 x 1-113 and Nev. 552 x 609) were compared for pea aphid resistance with the Polish alfalfa variety Miechowska and also with M. lupulina. None of the aphids feeding on M. lupulina survived more than 5 days. At the end of a two week period 520 aphids were alive on the Polish variety, Miechowska, compared with 120 and 99 on Nevada varieties 552 x 609 and 416 x 1-113, respectively.

6. Meadow Spittlebug. A method was developed at University Park, Pa., for screening alfalfa in the greenhouse during the winter months for resistance to the meadow spittlebug, Philaenus spumarius. The procedure consisted of planting oats in rows in greenhouse flats in April, caging field-collected adult spittlebugs for oviposition on the oat stubble in these flats in September and October, and storing them at 36 to 40° F until mid-December. Alfalfas to be screened were established in 1-inch peat pots in September. After mid-December flats were removed from cold storage and the potted alfalfas were planted between the rows of stubble. Flats with plants were held at 65 to 70° F in the greenhouse for 7 weeks and were then appraised for spittle masses and nymphs per plant. Masses ranged from 0 to 10, and nymphs from 0 to 26 per plant. Screening from January to May will allow more time for breeding studies with the more promising insect-resistant plant material.

7. Lygus Bugs. After two years of field screening, 38 alfalfa plants were selected for antibiosis cage testing in the greenhouse at Mesa, Ariz. Preliminary studies showed that 5 plants held promise for antibiosis type of resistance after 2 separate cage tests using third instar nymphs. Resistance was based on percentage of nymphal mortality using 5 nymphs per caged flower bud.

Research is being initiated at Manhattan, Kans., to develop techniques and screen alfalfa plants for resistance to lygus bugs and other mirid species under a grant awarded to Kansas State University of Agriculture and Applied Science.

8. Alfalfa Seed Chalcid. In studies at Mesa, Ariz., adults of the alfalfa seed chalcid, caged on the flowers, leaves, stems, and racemes of resistant and susceptible alfalfa plants, lived longest, 8.23 days, on the flowers. The average longevity on leaves was 6.51 days; stems, 4.61 days; and racemes, 4.42 days. There was no appreciable difference in longevity between resistant and susceptible plants. Longevity appeared to be influenced by rate of plant transpiration which was highest on the leaves.

9. Sweetclover Weevil. While an excellent source of resistance to the sweetclover weevil has been found in Melilotus infesta, this species does not readily cross with the commercial species. During the past winter evaluations were made on 24 accessions of M. dentata which, with the use of special techniques, will cross with M. alba. Three appeared to have intermediate levels of resistance and plants were selected from them for further study. Studies involving grafts between sweetclover weevil resistant (M. infesta) and susceptible (M. officinalis var. Goldtop) plant material show that there is little movement of the resistance factor across the graft union.

A grant jointly with the Crops Research Division was recently awarded to the Nebraska Agricultural Experiment Station to study the nature of the resistance of sweetclovers to the sweetclover weevil.

10. The Spittlebug, Prosapia bicincta. At Tifton, Ga., 81 bermudagrass hybrids were screened for resistance to damage by spittlebugs. Adults of both sexes were caged on the different grasses growing in 2-inch pots. The grass was observed daily for symptoms. None of the grasses showed resistance.

H. Insect Vectors of Diseases

1. Clover Viruses. At Poznan, Poland, under a P.L. 480 project bean yellow mosaic virus and red clover vein mosaic virus were simultaneously transmitted from crimson clover plants infected with both viruses to healthy crimson clover plants, by the green peach aphid, Myzus persicae, and the pea aphid, Acrythosiphon pisum. Both viruses were successfully transmitted to 50% of the test plants by the green peach aphid and to 40% by the pea aphid. Bean yellow mosaic virus alone was transmitted to 33.3 and 38.2% of the plants by the green peach aphid and the pea aphid, respectively. Red clover vein mosaic

virus was transmitted to 13.4 and 18.8% of the plants by these aphids. No symptoms appeared in 3.3% of the crimson clover plants fed on by infected green peach aphids and 3.0% fed on by the pea aphid.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology and Nutrition

Barnes, O. L. 1965. Tests for parthenogenesis in migratory, differential, and desert grasshoppers. J. Econ. Entomol. 58:173-4.

Byers, R. A. 1965. Biology and control of a spittlebug, Prosapia bicincta (Say), on coastal bermudagrass. Ga. Agr. Exp. Sta. Tech. Bull. N.S. 42.

Calkins, C. O. 1964. Factors influencing rate of feeding by the sweetclover adult. Entomol. Soc. Amer., No. Cent. Br. Proc. 19:66.

Connin, R. V. 1964. Notes on the biology of Hesperotettix viridis. J. Econ. Entomol. 57:606.

Jarvis, J. L. 1964. An association between a species of Caloglyphus (Acarina:Acaridae) and Phyllophaga anxia (Coleoptera:Scarabaeidae). J. Kans. Entomol. Soc. 37(3):207-210.

Manglitz, G. R. 1964. Spread of the western complex of the alfalfa weevil and resistance to insecticides. Entomol. Soc. Amer., No. Cent. Br. Proc. 19:67.

Parker, J. R. and R. V. Connin. 1964. Grasshoppers, their habits and damage. USDA Agr. Inf. Bull. 287.

Shotwell, R. L. 1965. Forecasting the hatching period of grasshoppers from weather data. USDA ARS 33-102.

Insecticidal and Cultural Control

Blickenstaff, C. C. 1965. Flaming - A new approach to alfalfa weevil control. Proc. Second Ann. Symposium - Use of Flame In Agriculture. St. Louis. Mo.

Skoog, F. F., F. T. Cowan, and K. Messenger. 1965. Ultra-low-volume aerial spraying of dieldrin and malathion for rangeland grasshopper control. J. Econ. Entomol. 58:559-565.

Insecticide Residue Determinations

Byers, R. A., D. W. Woodham, and M. C. Bowman. 1965. Residues on coastal bermudagrass, trash, and soil treated with granular endosulfan. J. Econ. Entomol. 58:160-161.

Varietal Evaluation for Insect Resistance

Gorz, H. J., G. R. Manglitz, and F. A. Haskins. 1965. Found - a weevil resistant sweetclover species. Nebr. Farm, Home & Ranch Quart. 11(4):8-9.

Howe, W. L., W. R. Kehr, and C. O. Calkins. 1965. Appraisal for combined pea aphid and spotted alfalfa aphid resistance in alfalfa. Nebr. Res. Bull. 221, 31 pp.

Jarvis, J. L. and W. R. Kehr. 1964. Evaluating alfalfa for resistance to the potato leafhopper. Entomol. Soc. Amer., No. Cent. Br. Proc. 19:64-65.

Kishaba, A. N., and G. R. Manglitz. 1965. Non-preference as a mechanism of sweetclover and alfalfa resistance to the sweetclover aphid and the spotted alfalfa aphid. J. Econ. Entomol. 58:566-569.

Manglitz, G. R., and H. J. Gorz. 1964. Host-range studies with the sweetclover weevil and the sweetclover aphid. J. Econ. Entomol. 57:683-687.

Newton, R. C. and D. K. Barnes. 1965. Factors affecting resistance of selected alfalfa clones to potato leafhopper. J. Econ. Entomol. 58:435-439.

AREA NO. 6. SOYBEAN AND PEANUT INSECTS

Problem. Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. Basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resist crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA AND COOPERATIVE PROGRAM

The Department has a limited program involving basic and applied research on the insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists, and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations.

The Federal scientific effort devoted to research in this area totals 1.5 professional man-years. Of this number 0.3 man-year is devoted to basic biology; 0.3 to insecticidal control; 0.5 to insecticidal residue determinations; and 0.1 to biological control; 0.1 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases; and 0.1 to program leadership.

PROGRAM OF THE STATE EXPERIMENT STATIONS

The States have an active program of research on soybean and peanut insects.

On soybeans, research is in progress to determine the amount and type of injury caused by various species of insects. Life histories and habits are studied under varied temperature and humidity conditions in the laboratory. Periodic field surveys are conducted to determine variations in seasonal population levels of insects on soybeans and other host plants. Control treatments are applied at different times through the season to establish

population levels necessary to cause significant damage.

Peanut insect research is concerned with seasonal history and habits of insect pests, determining economic infestation levels, chemical and cultural control and plant resistance studies. Biological information is being obtained as a basis for developing control programs. Rearing methods have been worked out for the most damaging species. Pests which appear sporadically are being studied to determine the factors responsible for outbreaks and the extent of injury they cause. Chemical controls and effects of tillage, irrigation and other management practices are evaluated under field conditions. The appearance of resistance in the southern corn rootworm to commonly used insecticides has necessitated intensification of non-chemical control research. Extensive comparisons of peanut introduction lines are being made and plants which exhibit resistance to insects are selected for further study and possible use in breeding programs.

There are 6.1 professional man-years devoted to soybean and peanut insect research in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Soybean Insects. At Tifton, Ga., lesser cornstalk borer moths were caught in 15-watt black light walk-in type traps, and in larger numbers than indicated by previous reports. More females were taken than males and about one-third of the females were mated and contained eggs at the time of capture. A method was developed for inducing egg-laying by the moths taken in light traps, and eggs have been obtained in large numbers for use in various biological studies.

At Columbia, Mo., studies of the biology of the broad-headed bugs, Coriscus pilosulus and C. eurinus revealed these insects undergo five nymphal instars. The development period from egg to adult required about 30 days. Approximately another 20 days ensue from adulthood until the first eggs are laid. Large numbers of C. pilosulus and C. eurinus were found mating in old soybean stubble on June 15. Approximately 50% of the eggs collected in the fall of 1964 hatched on removal from refrigeration in March 1965.

B. Insecticidal Control

1. Lesser Cornstalk Borer. In 1964 at Tifton, Ga., insecticides were applied in granular form at rates of 1 and 1/2 pound per acre (except dieldrin, which was applied only at 2 pounds) over rows of seedling cowpeas in the 2-leaf stage of growth.

The insecticides used were dieldrin, trichlorfon, ethion, diazinon, fenthion, Bayer 25141, Union Carbide 10854, Bomyl, and triphenyltin hydroxide. The first five gave effective control of the insect.

Chemagro 25141, American Cyanimid 47031, Mobil MCA-600, and UpJohn-12927 were applied to soybean plants as sprays at 4, 8, and 16 ounces per acre. At intervals samples of the foliage were obtained from each plot, taken to the laboratory and fed to 4-day-old fall armyworm larvae. Chemagro 25141 treated plots were sampled at intervals up to 20 days and all rates gave good control during this period. The plots treated with AC 47031 were sampled at intervals up to 12 days. Control with the 16-ounce rate ranged from 60 to 100% through the 8th day, but was negligible on the 12th day. The 4 and 8 ounce rates gave poor control. Foliage from plots treated with MC-A-600 were sampled at intervals of 0, 1, 3, and 4 days. Control with the 4-ounce rate was 94% immediately after treatment, 33% for the 1-day sample, and negligible thereafter. The 8-ounce rate gave immediate control of 99% but dropped to 14% for the 3-day samples. The 16-ounce rate gave 100% immediate control, 98% at 1 day, 30% the 3rd day, and 20% the 4th day. The plants treated with U-12927 were sampled at intervals up to 21 days. The 4-ounce rate gave 100% immediate control, 88% after 1-day, and 44% or less after the 2nd day. The 8-ounce rate gave 96 to 100% control the first 2 days, 83% the 3rd day, and 56% or less after the 6th day. The 16-ounce rate gave 90 to 100% control through the 6th day, 70% through the 10th day, and 56% or less on the 13th day and later.

C. Insecticide Residues

1. Imidan. At Tifton, Ga., soybean plants were treated with sprays of Imidan at 4, 8, and 16 ounces per acre. Samples of the treated plants were taken as soon as the sprays had dried and at intervals of 1, 2, 4, 7, 14, and 21 days. The residues in ppm were: for the 4-ounce rate, 14.32, 0.95, 0.75, 0.36, 0.05, and 0.04, (21-day sample lost); the 8-ounce rate 20,60, 2.33, 1.09, 0.68, 0.16, 0.13, and 0.04; for the 16-ounce rate, 48,29, 4.66, 2.10, 1.41, 0.64, 0.42, and 0.16. The samples were anlyzed by the total phosphorous method.

2. Parathion on peanuts. At Tifton, Ga., granular parathion was applied to peanuts at 2 pounds per acre to control the southern corn rootworm. Analyses showed that there were no detectable residues of parathion present in the peanuts.

D. Varietal Evaluation for Insect Resistance

1. Soybean Insects. At Columbia, Mo., approximately 30 varieties which appeared to show some resistance to stinkbug were selected from 100 varieties of soybean plant introductions. The varieties were evaluated in a field cage, 12' x 6' x 60', which contained approximately one green stinkbug (Acrosternum hilare) per square foot. The longer maturing varieties were more heavily damaged but there was no significant resistance shown by any of the 30 varieties.

2. Peanut Insects. At Tifton, Ga., laboratory produced eggs of the lesser cornstalk borer are being used to infest 14 selected peanut varieties growing in the field in order to evaluate them for resistance to this insect.

E. Insect Vectors of Disease

1. Soybean yeast spot. Field and laboratory tests conducted at Columbia, Mo., demonstrated the capability of Euschistus tristigmus in transmitting yeast spot disease to soybeans. Cage and laboratory tests involving the broad-headed bug, Corsicus pilosulus demonstrated that this insect also transmitted yeast-spot disease. A total of seven species of hemiptera in two families has been shown to transmit this disease to soybeans in the field.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Daugherty, D. M., M. H. Neustadt, C. W. Gehrke, L. E. Cavanah, L. F. Williams, and D. E. Green. 1964. An evaluation of damage to soybeans by brown and green stinkbugs. J. Econ. Entomol. 57:719-22.

Leuck, D. B., and Ray Hammons. 1965. Further evaluation of the role of bees in natural cross-pollination of the peanut, Arachis hypogaea L. J. Econ. Entomol. 57:94.

AREA NO. 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem. Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of $900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in 68 counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to maize dwarf mosaic and corn stunt recently found in several North Central and Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly, wheat jointworm at Lafayette, Ind., and Manhattan, Kans.; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem

sawfly at Fargo, N. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., State College, Miss., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts and grants on the biology and control of the cereal leaf beetle with Michigan, Indiana, and Ohio Experiment Stations, soil insects attacking corn with the University of Nebraska, and vectors of corn stunt virus with Mississippi State College, nature of resistance of corn to the European corn borer with Iowa State University, and insect communication in the infrared region with Michigan University, Ann Arbor, Mich.

The Federal scientific effort devoted to research in this area totals 42.5 professional man-years. Of this number 10.8 is devoted to basic biology, physiology, and nutrition; 3.5 to insecticidal and cultural control; 1.8 to insecticide residue determinations; 4.1 to biological control; 2.9 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 15.7 to varietal evaluation for insect resistance; 1.8 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize With Special Reference to Stalk Borers".

PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research is in progress in the States on insects affecting corn, sorghum and small grains. Biological information is being obtained on a variety of pests. Data acquired include overwintering habits, time of emergence, food habits, interspecies competition, mating, oviposition, migratory, and dispersion habits and longevity. This information is being

used to develop methods of predicting the incidence of pest outbreaks.

Ecological studies are being performed to determine the effects of temperature and other factors such as plant growth, soil conditions, and crop sequence on population levels. The influence and efficiency of various natural enemies are also being evaluated.

Cultural control techniques including the effects of fertilizer applications, soil management practices, time of seeding, irrigation, stubble mulch, and grazing receive their share of attention.

Experimental insecticides are tested for their effectiveness. Samples of treated crops are analyzed for harmful residues. Insecticide treatments are also used to determine the degree of infestation which crops can tolerate before control becomes necessary.

Research on artificial rearing is performed to develop methods for providing insects for year round study and for uniform infestation in plant resistance work. Plant varieties, hybrids and lines are evaluated in the field and in nursery plots for their resistance to insect attack. Crosses are made to increase resistance levels and biological, physiological, and chemical studies are conducted to determine the nature of the resistance.

Vectors of plant diseases are studied to increase our knowledge of insect-plant relationships which could lead to the control of the vector and, consequently, the disease. The roles of alternate host plants and vector seasonal life history and flight patterns are being studied. The effect of the disease organism on vector biology, morphology, and cytology is investigated.

There are 49.5 professional man-years devoted to research on corn, sorghum, and small grain insects in the States.

PROGRESS USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

1. Corn Insects. Studies were continued on interrelation of factors affecting control of the European corn borer in Boone County, Iowa. The 1964 early spring survey showed a population of 4,228 borers per acre, and the late spring survey showed 3,250 borers per acre. This was a reduction of 64.2% from the postharvest survey conducted in 1963. The midsummer borer population in 1964 averaged 5,416 borers per acre and 94% of the first-brood borers pupated. The 1964 fall population averaged 7,478 borers per acre prior to harvesting whereas the postharvest survey revealed 2,040 borers per acre.

Light trap catches at the Ankeny farm indicated only 2 generations of corn borer were present during the 1964 growing season.

In connection with NC-20, laboratory and field experiments were conducted with borers from Minnesota, Iowa, and Missouri to investigate the possibility of the existence of biotypes. The results indicate that there are at least 2 biotypes of the corn borer, the northern in which a percentage of the population undergoes obligatory diapause and the southern in which a large percentage of the population undergoes facultative diapause. It appears that diapause in the corn borer is determined genetically in addition to other factors that have been demonstrated to cause this condition. The results of the experiments lead to the theory that diapause in this insect is governed by a multigenetic makeup which responds to changes in temperature and photoperiod. The concentration of the genes in an individual determines the extremes of temperature and photoperiod that can be experienced before diapause is induced. Thus, an individual larva with a low concentration of diapause inducing genes could withstand shorter days and cooler temperatures without inducing diapause than one with a high concentration of diapause inducing genes.

Methods of rearing European corn borer in the laboratory have been further refined. When strips of corrugated paper were placed in the rearing container mature larvae entered the paper to pupate. The paper can then be transferred to emergence cages without handling each pupa. Leaf factor material used in the diet is now cut with a field chopper and dried in a commercial grain dryer.

The laboratory colony of borers begun in August of 1963 has been continued and is now in its 25th generation. No major change in the insect is evident from the early generations to the 24th, although there may be a trend for pupal weights to be slightly higher. This colony, and 3 sub-colonies, have provided egg masses for year round use in all laboratory studies of the various projects.

A study at Wooster, Ohio, indicates that the chromosomes of the European corn borer have a diffuse centromere, thus broken chromosomes would migrate to the poles at meiosis just like whole chromosomes.

In studies at Brookings, S. D., it was found that larvae of the western corn rootworm required a relative humidity of 98% or above to survive more than 11 hours. Therefore, larvae hatching in the top few centimeters of dry soil exposed to direct sun might be desiccated before finding food and a suitable environment.

Western corn rootworm eggs exposed to temperatures of 5° F or below for one week did not hatch while eggs exposed to 14° F hatched. Even in severe winters in South Dakota temperatures in the soil where the eggs are seldom go below 14° F.

The recent outbreaks of resistant western corn rootworms and spread of these resistant populations to new areas of the Corn Belt have brought this insect and the northern corn rootworm into overlapping areas, and the two species have

been observed mating. In laboratory matings of the two species, all offspring reared to the adult stage were, by all available criteria, western corn rootworms. The few individuals reared to the adult stage were inbred and one male was backcrossed to a lab reared western female. The hybrid laid 329 eggs, 90% of which hatched. The backcross was also fertile, which ruled out male hybrid sterility. Further inbreeding through three generations produced fertile offspring resembling the western corn rootworm.

Larvae of the western corn rootworm have been reared to adults on a diet consisting of a variation of the pink bollworm diet with an additional corn kernel plant factor, but the development was slow and small adults with deformed wings were produced, indicating nutritional deficiencies and possible absence of feeding arrestants.

The feeding, resting, and movement behavior of the northern, western, and southern corn rootworms were compared under field conditions. All three species preferred succulent silks and ears for food when present. The northern corn rootworm was found in larger proportions than the western corn rootworm on these parts. Greatest foliage feeding by the western corn rootworm was apparent. Adult migration and movement was strongly correlated with increased corn maturity and suggested that movement or spread of the western species to new areas occurs during the late season period when older corn is less desirable as food. The southern corn rootworm moves to other crops after adult emergence in corn fields. The percentage of the aldrin and heptachlor resistant western corn rootworms to total rootworm population gradually increased from practically none in 1962 to 22% in 1964 in the Brookings, S. D., area.

In Nutritional studies with the corn leaf aphid, one diet was developed which could sustain survival and reproduction over a three week period. A 20% sucrose solution was optimum in basic diets. Water extracts from seedling corn incorporated in the diets failed to inhibit aphid survival or reproduction. It was concluded that young plants contain no deleterious substance to this aphid species even though it does not colonize on seedling corn under field conditions.

A mass rearing method for the southern and western corn rootworms has been developed at Brookings, S. D. The relatively simple procedure involves larval development in shallow screen-bottom trays thickly planted with corn in a 1:1 vermiculite-soil mixture. The dense root mat in a single 12" x 18" tray supplies ample foot to mature 200-250 larvae. A single transfer of the infested mat to a greenhouse flat affords an ideal site for pupation and adult emergence.

The corn earworm continues to be the most important corn insect in the South and caused an estimated loss of over $5,000,000 in the 6-State area of Alabama, Florida, Georgia, North and South Carolina, and Mississippi in 1964. The southwestern corn borer has continued to spread in Mississippi and Alabama.

At Tifton, Ga., a vitamin mixture, recommended and commonly used for rearing lepidopterous larvae, was found to be deficient in two vitamins, folic acid and vitamin B_{12}, when used in a fall armyworm diet. The substitution of another vitamin mixture containing the two vitamins in sufficient amounts has almost entirely eliminated insect deformities experienced in previous attempts to rear this insect.

Research on the theory that insects locate and communicate by means of infrared and microwave radiation has continued at Tifton, Ga. Experiments with flight activity of noctuid moths under different lighting conditions have shown that mating is highest with ultraviolet and cool-daylight fluorescent lights alternating with darkness. The results indicate that conditioning the insects with ultraviolet and visible radiation contribute to their efficiency of receiving infrared and microwave radiation in darkness.

An infrared blackbody was constructed which eliminated all visible light but allowed radiation of secondary emission in the 8 μ to 13 μ region. Six different species of noctuid moths were attracted to the radiating blackbody in a totally dark room, whereas nonemitting blackbody controls did not attract any moths.

The following percentages of infrared transmission were obtained when the corneal lens of sphingid moths were cleaned and mounted in an infrared spectrophotometer: 2.5 to 2.85 μ, 40%; 3.5 to 5.7 μ, 50%; 7.5 to 8.8 μ, 15%; and 10.3 to 13.0 μ, 40%. All fall within atmospheric windows, indicating that the outer lens of the moth eye can transmit infrared radiation.

In Mississippi biological and ecological studies of the southwestern corn borer revealed that moths were attracted to mercury vapor and black light traps set up adjacent to corn fields. Mercury vapor light was more attractive than black light. Biological investigations showed that diapause was induced by 13 and 14 hours of light, although twice as many larvae entered diapause at 13 hours than did at 14 hours. In light chambers used for this study diapause was prohibited by using a 30-minute light period daily in the middle of the 11-hour period of darkness.

Research conducted in India under P. L. 480 project A7-ENT-25 showed that Chilo zonellus is the major pest of maize and progress was made on mass rearing of this pest and also Sesomia infirens.

2. Small Grain and Sorghum Insects. At Brookings, S. D., successive generations of a false wireworm Eleodes suturalis have been continuously colonized and mass produced in the laboratory. The continuous availability of a coleopterous soil inhabiting insect provides a test organism for soil insecticide screening and bioassay, as well as a subterranean species for basic research in fields of toxicology, physiology, and ecology.

At Tifton, Ga., the corn earworm and fall armyworm utilization of sorghum leaves and heads was compared with corn leaves and kernels. Although smaller

in size, the fall armyworm larvae utilized more of each plant part than did the corn earworm larvae. Both species of insects utilized corn kernels better than corn leaves, sorghum heads, or sorghum leaves. Corn plant parts were utilized to a greater extent by both species than sorghum plant parts.

Environmental factors responsible for corn leaf aphid flight initiation have been studied at Tifton, Ga. There was a significant positive correlation between actual barometric pressure and number of aphids initiating hourly flight, and there was an indication that high concentrations of negative ions increased aphid flight.

At Stillwater, Okla., artificial diets for rearing lepidopterous larvae have been improved by increasing the amount of formalin and adding propionic acid. This reduced mold development, and larval production was increased.

Third instar corn earworm and fall armyworm larvae reared on artificial diets, when placed on 30-day old RS 610 sorghum in the greenhouse, fed readily, and the leaves showed damage typical of naturally infested sorghums. This test demonstrated the practical use of larvae mass-reared on artificial diets for use in manual infestations in connection with searching for resistant germ plasm.

Work was initiated at East Lansing, Mich., on mass rearing of the cereal leaf beetle. Field collected and laboratory reared adults were capable of mating and egg production after 6 weeks' hibernation when confined in an oviposition chamber at 40° F. After hatching the larvae are transferred to flats of barley, where the soil of the flat has been covered with plaster of paris and sand, to complete larval development and pupation. Pupae are removed and held for adult emergence. This method of rearing has provided access to the pupal stage and has greatly increased production of adult forms.

Flight of the cereal leaf beetle was found to be greater at temperatures above 75° F than at lower temperatures; between 12:00 noon and 3:00 p.m. than at other times; at 3 feet than at 6 or 11 feet; and with summer adults than with spring adults. Temperature and the related time of day proved to be the most important factors affecting flight. The pest tended to fly with the wind, but the influence of wind velocity and cloud cover were minimal on the amount and height of flight. Large numbers of both spring and summer adults were found to move 1-1/2 miles during their period of activity.

Developmental limits of the cereal leaf beetle were found to be 52° to 90° F with an optimum of 80° and 85° F for all stages. The diapausing adult was able to survive at 0° F and all stages could survive at 110° F. Three years of study of the pest in the field have shown that the different stages were found to be "common" (i.e. easily found) at: spring adults, 37.5 to 68.5 day-degrees with a base of 52° F; eggs, 65.5 to 90.8 day-degrees; larvae, 249.3 to 250.5 day-degrees; pupae, 510.5 day-degrees; summer adults, 764.5 to 786.5 day-degrees.

A 1:1 sex ratio was determined for both spring and summer adults of the cereal leaf beetle and egg production is estimated at 96 eggs per female in the field. Natural mortality of the different stages of the pest is estimated at: eggs, 34% in winter wheat, 19% in spring oats; larvae (the greater part in failure to enter pupation) 68% in wheat, 60% in oats; pupae, 68% in wheat, 60% in oats; 60% of the overwintering adults; and minor mortality of active spring and summer adults. The differences in egg mortality between wheat and oats is caused by lower temperatures during the period that the eggs are in the wheat than in the oats and in almost equal part by predation, principally by the lady beetle Coleomegilla maculata lengi in the wheat. Mortality during the pupal stage (including failure of the larvae to form pupae) is attributed to high soil temperatures and the overwintering kill is attributed to prolonged exposure to low temperatures with moisture and predation being of relatively minor importance. With about 3.4 times more eggs layed in oats than in wheat, the population increase of the pest is estimated at 369% per year.

B. Insecticidal and Cultural Control

1. Corn Insects. Twenty-four insecticides were tested in granular formulations against first-generation European corn borer larvae at Ankeny, Iowa. The most effective compound in the test was methyl parathion at 1.0 pound per acre but this was not significantly better than DDT at 1.0 pound per acre. Thirteen other compounds gave good control. Of the 16 compounds tested in granular formulations for control of second-generation borers, 10 appeared to be as effective as DDT. Fifteen insecticides were tested in spray formulations against first-generation corn borer and 7 were more effective than DDT.

Of several compounds tested for systemic control of corn borer larvae in field corn, only American Cyanamid 47470 at 2.0 pounds and 4.0 pounds actual insecticide per acre was effective.

In toxicological studies with the western corn rootworm at Brookings, S. D., the aldrin LD_{50} values for third instar larvae were higher than for adults of aldrin resistant western corn rootworm collected from the same fields. There was a definite trend toward decreasing LD_{50} values for adults as the growing season progressed. The average aldrin resistance in the eastern range of distribution of western corn rootworm has increased 26 to 199% over the levels obtained in the same localities in 1963. Although there are scattered areas where northern corn rootworm manifest aldrin resistance, the incidence of resistance is relatively static. Both species of corn rootworm appear to remain quite susceptible to the action of diazinon and phorate.

Previous studies indicated that the resistance mechanism in western corn rootworm involved the epoxidation metabolism of Cl_{36} labelled aldrin and dieldrin. Preliminary studies with C_{14} labelled material indicate that there were at least two additional major metabolites (besides aldrin and dieldrin) not present in the Cl_{36} studies. It is possible that one of these metabolites represents the dechlorinated insecticide.

Varied cultural practices were investigated for western corn rootworm control. Different discing and plowing sequences in both the spring and fall had no significant effect in reducing rootworm larval populations. There were 7 times more overwintering rootworm eggs in plots where corn was allowed to mature than when cut for silage in late August.

At Tifton, Ga., five applications of any of the following compounds when applied at the rate of 1 pound per acre gave corn earworm control equal to or better than 2 pounds of DDT per acre: SD-9129 and SD-8447, Mobil Oil MCA-600, Niagara NIA-10242, UpJohn U-12927, Stauffer R-5092, and General Chemical GC-4072.

In Mississippi early planting was found to minimize southwestern corn borer injury to corn. Three weekly applications of endrin at 0.5 pound per acre starting when second generation larvae hatched, gave 77.2% control.

Research conducted in Nebraska under contract showed that the western corn rootworm was developing resistance to phorate in some areas. Several experimental organic phosphate insecticides appear to be as effective or better than those now recommended.

2. Small Grain and Sorghum Insects. At Stillwater, Okla., hybrids and parental lines of sorghum were sprayed with insecticides at recommended rates to measure differential insecticide phytotoxicity. All entries except RS 610 and RS 626 showed phytotoxicity following spraying with methyl parathion and Bidrin, with leaf area damage ranging around 50%. Ethion, diazinon, and carbaryl W.P. and the water sprayed check plots did not show injury. Yield reductions resulting from phytotoxicity were not as great in 1964 as they were in 1963. Temperature and plant condition, undoubtedly, are associated with insecticide phytotoxicity and yield reduction.

Several insecticides were found to be superior to parathion for greenbug control in laboratory tests. These included emulsifiable concentrates of GC-6506 and GC-3707. Two 10% granular formulations, UC-21149 and NIA-10242, provided a faster "knockdown" than Di-Syston granules and provided 100% greenbug control at the rate of 0.063 pound per acre under greenhouse conditions.

In greenhouse insecticide screening tests there were indications that greenbugs might be developing resistance to parathion. Previously, 100% control was obtained in the laboratory with parathion spray at the rate of 0.016 pound per acre, but more recently, the rate of 0.125 pound per acre (8 times the rate used formerly), failed to give satisfactory control.

In Montana no insecticides tested for control of wheat stem sawfly were as effective as heptachlor. An additive, dimethyl sulfoxide, appeared to enhance the penetration of Meta-Systox when applied to wheat foliage.

In aerial application tests conducted under contract in Michigan, technical malathion applied at the rate of 4 liquid ounces per acre was as effective as 5 liquid ounces against the spring adults of the cereal leaf beetle. The use of "mini-spin" nozzles for the aerial spray resulted in a slower initial kill but a longer residual effectiveness of the malathion than did flat tip nozzles.

Laboratory tests were conducted to determine the toxicity of carbaryl, malathion, and dieldrin to cereal leaf beetle adults. Topically applied concentrations of the insecticides demonstrated LD_{50}'s of 0.007% µg per beetle, 0.01 µg per beetle, and 0.018 µg per beetle for carbaryl, dieldrin, and malathion, respectively.

ENT-25784, endosulfon, Meta-Systox R, Geigy 13905, General Chemical 9160 and 4072, Niagara 10242, Shell 8530, ENT-25736, Baygon, Mobil MCA-600, and Stauffer B-10119 as foliage sprays, and Union Carbide 21149 as a soil-applied systemic, showed promise against the larvae of the cereal leaf beetle.

C. Insecticide Residue Determinations

1. Residues on Corn. Soils from Ankeny, Iowa, were analyzed for American Cyanamid CL47470. Samples were taken at 2 to 6 inches, 6 to 10 inches, 10 to 14 inches, and 14 to 18 inches at 0, 1, and 7 days after the compound has been applied to the soil in a band parallel to the corn row at a rate of 2 pounds per acre. Results of these analyses indicate that there was very little movement of the pesticide in the soil during the 7-day period.

At Tifton, Ga., in studies of Shell SD-8447 applied to sweet corn as a wettable powder at rates of 1/2, 1, and 2 pounds per acre, electron affinity gas chromatography analysis revealed that initial residues on the stalks and leaves were about the same as those on ear husks. However, the residues on the husks diminished faster. The level of residue on both plant parts varied directly with the quantity of insecticide applied and after 16 days of weathering only 0.42 and 0.02 ppm of the insecticide remained on the stalks and leaves and on the ear husks, respectively, in plots treated with the highest rate. No detectable residues were found in the ears after 16 days weathering in the field.

2. Residues on Small Grain and Sorghum. Heptachlor was applied as a 5% granular formulation in the furrow with wheat seed at planting at the rate of 1/2 or 1 pound per acre. No measurable residues of heptachlor were found in the green wheat 71 days after planting, but residues of heptachlor epoxide were 0.011 ppm for the 1-pound dosage and 0.015 ppm for the 1/2-pound dosage. When the grain was harvested 146 days after planting, no measurable residues were found in the grain. Straw samples taken at harvest contained no measurable residues of heptachlor, but heptachlor epoxide residues of 0.010 ppm for the 1-pound dosage and 0.045 for the 1/2-pound dosage were present.

D. Biological Control

1. Corn Insects. Field and laboratory tests with the bacterium Bacillus

thuringiensis in Iowa continue to show its potential usefulness as a microbial insecticide for European corn borer control. Granule formulations controlled field infestations of the European corn borer as well as the recommended insecticide DDT. Preliminary field tests with encapsulated bacterium also indicated good borer control. The encapsulation process appears to provide a broad spectrum of opportunity in insecticide and microbial formulation. Capsules can be tailored to size and conditions of breakdown. Both liquids and dry material can be encapsulated. Other forms of life than those to be controlled can be protected from toxic chemicals, tastes can be masked, and microorganisms susceptible to environmental conditions can be protected. Formulations containing materials for immediate release can be applied at the same time with materials encapsulated for later breakdown and release.

Investigations involving the borer-infecting protozoan Perezia pyraustae indicates that the epithelial lining of the young borers' alimentary tract is heavily invaded, but the infection in this tissue is transitory. Under field conditions such larvae would have trouble becoming established, since the gut wall cells could not function normally.

The distribution and abundance of exotic parasites of the European corn borer were determined from larvae collected in 14 States. Parasitism was above 10% in Iowa and Maryland, and ranged from 1.5 to 6.9% in the other 12.

A nematode, Mesodiplogaster sp., isolated from soil at Brookings, S. D., has proved to be lethal to infected corn rootworm larvae and pupae. All infected insects perish in one to three days. The beetle or eggs are apparently not affected. The nematode is easily reared aseptically on cooked pork kidney cubes placed on water agar slants. Preliminary research in Illinois has shown this organism will also infect and kill the onion maggot.

At Tifton, Ga., field releases have been started on two species of tachinids obtained from India in connection with P. L. 480 projects. The species, Drino imberbis and Piparyia tachinid sp. #3, parasitize large corn earworm larvae and are easily reared in the laboratory. They will also parasitize the tobacco budworm and the fall armyworm but appear to develop better on the corn earworm. A small braconid parasite from India, Microplitis sp., was able to parasitize both the corn earworm and the tobacco budworm in the laboratory.

Native parasites were reared from corn earworm collected on wild host plants. Micropolitis croceipes was reared from the corn earworm collected on crane's bill. Campoletis sp. was found parasitizing corn earworm larvae on toad flax. Two species of tachinids were reared from fall armyworms collected on Coastal bermudagrass and millet. The more abundant tachinid was Lespesia archippivora. Winthemia rufopicta was less abundant. A colony was established of Lespesia archippivora which proved easy to rear in large numbers using the same techniques which were developed for Drino and Piparyia. An egg parasite, Trichogramma sp., was collected in the corn field early in the summer by exposing corn earworm eggs on pieces of paper napkin clipped to corn leaves.

At Tifton, Ga., the nuclear polyhedrosis virus of the corn earworm was used in an early season field trial on sweet corn in which the virus alone and in combination with DDT was compared with a DDT standard and an untreated control. The best control was obtained with a combination of virus and DDT applied at the early-tassle treatment and at 3-day intervals during silking. There was no significant difference between: (1) DDT alone applied to the tassle stage followed by treatments at 3-day intervals in the silking stage, (2) the virus alone applied to the tassle stage followed by treatments at 3-day intervals during silking, or (3) a single virus treatment applied during the tassle stage. All were significantly better than the untreated control.

2. Small Grain and Sorghum Insects. In Finland studies were continued on population dynamics of the leafhopper, Calligypona pellucida under P. L. 480 project E8-ENT-1. A triungulid Elenchus tenuicornis was found to be an important parasite of C. pellucida and the biology of the parasite has been investigated.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. Results of investigations carried on during 1964 at Ankeny, Iowa, indicate that chemosterilants can be used to sterilize European corn borer adults by treating partially developed larvae. When 5-day-old larvae were placed for 24 hours on hempa-treated diet the resulting male moths were 90% sterile. The longevity and mating rate of the treated moths compared favorably with the untreated moths. Two to four times as much chemosterilant was required to sterilize the female moths as the male moths.

Third, 4th, and 5th instar corn borer larvae have been irradiated at dosages ranging from 2,000 to 20,000 roentgens, in 500-r increments, to determine the effect of gamma rays on growth, pupation, mating, egg production and hatch. Dosages above 10,000 r prevented larvae from pupating but did not prevent their growth to pupation size. Although pupation was nearly normal at 5000 r, the adults which emerged were abnormal morphologically. At dosages up to 4000 r, growth, pupation, emergence, and mating were apparently normal. From these experiments it would appear that 3rd instar larvae, or larvae in diapause, could be sterilized practically with a dosage of about 3000-3500 r.

In connection with the irradiation experiments, histological and cytological studies are being carried out on spermatogenesis and sperm formation in normal, irradiated, and chemosterilant-treated European corn borers. Testes are fixed, embedded, and sectioned for both light and electron microscopy. These studies indicate that 3rd instar testes contain mostly primary and secondary spermatogonia, 4th instar testes contain all stages up to early spermatids, and 5th instar testes contain even mature spermatozoa. Testes in diapausing 5th instar larvae contain mostly spermatocytes in an arrested stage of development.

At Tifton, Ga., testing of ether extracts from virgin fall armyworm, corn earworm, and armyworm moths has shown that a specific mating stimulant (sex pheromone) is produced by the female of each species. In all three insects the

lure was found within the last two abdominal segments. Attempts to recover the pheromone from heads, thoraces, and/or upper abdominal segments have failed.

When male fall armyworm moths, 3 to 6 days old, were exposed to 0.2 equivalents of females of different ages, only 2% of the males reacted to extracts of females 12 hours old, 32% reacted to extracts of females 24 hours old, 80% to females 36 hours old, and 98% to females 48 hours old. When 3- to 6-day-old males were exposed to varying concentrations of extracts of 3-day-old females, 98% of the males reacted to 0.02 female moth equivalents (FME), 88% reacted to 0.002 FME, 66% reacted to 0.0002 FME, and 20% reacted to 0.00002 FME.

At Tifton, Ga., tepa was found to sterilize the armyworm, Pseudaletia unipuncta. Treating fall armyworm moths with hemel and hempa by feeding, tarsal contact, or topical application did not reduce egg hatching, number of eggs laid, or mating frequency. Male fall armyworm moths sterilized with tepa competed with untreated males for untreated females and mated as frequently as did the untreated males.

2. Small Grain and Sorghum Insects. By the use of a specially designed soil olfactometer, a substance has been discovered which attracts larvae of E. suturalis. Larvae move through soil in response to the attractant. The substance appears to be a product of seed germination. Air passed over wet or dry wheat kernels or over ground wheat will not attract. Although it appears to be a product of seed germination, there seems to be a concentration factor where it becomes a repellent or a second substance or substances become a repellent at high concentrations.

In studies conducted under contract in Michigan, diapausing females of the cereal leaf beetle were sterilized by exposures of 3000 roentgens of radiation. The gonads of the females do not mature until after they have undergone diapause, but the male gonads are fully developed upon emergence and before diapause.

In Michigan 370 synthetic compounds were evaluated as possible attractants for spring adult cereal leaf beetle and 250 for summer adult beetles. None were highly attractive to the beetle, but a few showed responses greater than the check. All tests with natural lures were negative.

Ether, ethanol or water extracts from barley, oats, wheat, corn, or beans induced no response to cereal leaf beetle adults. However, seedling plants of barley or oats when placed in bean fields attracted many beetles. When 16 different colors were tested for response of cereal leaf beetle, counts of beetles collected indicate a high preference for canary yellow, followed by white, ivory, orange, and pink, in that order. Blue, red, and black attracted very low numbers, black being nearly nonattractive.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. At Tifton, Ga., entomologists in cooperation with

agricultural engineers, installed a fan on an ultraviolet light trap in order to force the "catch" into a treating chamber. The chamber is coated with a chemosterilant suspended in a 10% sugar solution and allowed to dry. Fall armyworm and corn earworm moths come in contact with the chemosterilant by feeding and/or by tarsal contact. After predetermined exposure the moths are allowed to escape back onto the environment for competition with untreated moths for mates.

At Tifton, Ga., agricultural engineers worked with entomologists and chemists to develop a high clearance tractor-mounted revolving brush applicator to treat corn silks for corn earworm control. Applications at the rate of 1.3 pounds per acre produced two to four times more insecticide residue on ear tips than emulsion sprays applied at the rate of two pounds per acre. The brush applications resulted in as good earworm control as that obtained with emulsion sprays.

Agricultural engineers and chemists at Tifton, Ga., evaluated the efficiency of an electrostatic duster to place dust on the upper and lower surfaces of leaves. Utilizing DDT dust and 10-day-old bean plants they found that deposits of insecticide on the top surfaces of leaves were about 57% greater from charged nozzles than from uncharged nozzles and that residues on the bottom surfaces were about 310% greater from charged nozzles. In tests with uncharged nozzles, the quantity of insecticide found in the bottom surfaces of the leaves represented about 11% of the total on both sides, while with the charged nozzles the residue on the bottom surfaces accounted for about 25% of the total.

2. Small Grain and Sorghum Insects. Four types of traps are being used in South Dakota for sampling of aerial cereal aphid populations. These include yellow pan, Shands type directional wind traps, a revolving net trap, and a Johnson-Taylor suction trap. Yellow pans have proven to be ineffective cereal aphid traps in South Dakota but are being continued in cooperation with NC-67. Shands trap catches vary directly with wind velocity and are useful for detection of aphids but not for population comparisons between years or areas. The revolving net and Johnson-Taylor traps are efficient aphid catchers and sample constant volumes of air.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. Only 3 of 100 inbred lines developed by State and Federal corn breeders from the Southern Corn Improvement Conference area had a satisfactory degree of resistance to first-brood European corn borer at Ankeny, Iowa. Six of 35 Southern inbred lines indicated a satisfactory degree to second brood resistance.

Translocation corn stocks were used to determine which chromosome arm(s) of the resistant inbred line B49 carries gene(s) for resistance to corn borer leaf feeding. These results indicate that B49 possesses a gene for resistance on the short arm of chromosomes 1, 2, and 4; and on the long arms of chromosomes 4, 6, and 8.

A study was initiated in 1964 that involved 3 permutations of each of 12 double cross hybrids and their nonparental single crosses. The double crosses (containing 0 to 4 European corn borer resistant lines) were made up of some combination of 8 inbreds (B49, C.I.31A, HD225, and B46 = resistant; B14, WF9, B37, and M14 = susceptible). Previous investigations have indicated that B49 and C.I.31A contribute a higher degree of resistance when in crosses with susceptible lines than HD225 and B46, and that susceptible B14 exhibits some degree of tolerance when in hybrid combination. Double crosses with B49 and C.I.31A plus either one or both of B46 and HD225 were rated resistant. Double crosses with B49 and C.I.31A with 2 susceptible lines rated as intermediate or better. Double crosses with both B49 and B46 were no better than when B49 was the only resistant line in the pedigree, and these crosses rated intermediate for leaf feeding. The double cross with B46 as the sole source of resistance was as susceptible as the double cross made up of 4 susceptible inbreds. The permutations of some of the double crosses differed from each other. This would be an indication of some degree of non-additive gene action being an operative force in resistance to corn borer leaf feeding.

In a greenhouse experiment substances were added to a resistant line, C.I.31A to see if it could be made susceptible. Four different treatments (1. vitamins plus dextrose, 2. vitamins, 3. dextrose, 4. distilled water) were injected into the plant through the side above the growing point. This treatment often caused an adverse effect on the plants, even when distilled water was injected. The vitamin plus dextrose treatment was not significantly different than the distilled water treatment. Dextrose alone was as good as vitamin plus dextrose, but vitamins alone had some detrimental effect on larval survival.

A few WF9 selections that originated from the breeding program of transferring corn borer resistance into WF9 germ plasm were evaluated when crossed onto 4 inbred testers. The original WF9 was the most susceptible entry in the test. Although the WF9 selections do not possess a high degree of corn borer resistance when in hybrid combination, they do appear to contribute some resistance.

In another test a commercially available fertilizer (which is readily soluble in water), amino acids, vitamins and dextrose were injected into corn hybrids or inbreds to determine their effect on larval survival and development. On the resistant corn, C.I.31A X B49, the survival was low on all treatments, but the check treatments were the lowest followed by the soluble fertilizer and amino acid treatments. Some of these treatments gave significant increases in larval survival, but the differences were not of the magnitude necessary to account for resistance. There were no significant differences between treatments on the susceptible cross, WF9 X B37, except the treatment of soluble fertilizer plus dextrose, which had a significantly lower survival than the other treatments.

The results from the resistant C.I.31A material were not very conclusive because of the low survival under all treatments. Vitamins, amino acids plus dextrose, and vitamins plus dextrose gave the highest survival on susceptible

WF9. The distilled water treatment was not significantly different from the untreated check.

Another study in 1964 involved plant juice (by use of a plant press) from the whorl area of C.I.31A and WF9. The "juice" of C.I.31A was put into the whorl area of WF9 plants with a hypodermic needle, and the juice of WF9 plants was put into plants of C.I.31A. There were no significant differences between treatments. However, the larval survival in this test was very low.

In a greenhouse test in late 1964 all of the ingredients of the corn borer synthetic diet except agar, leaf whorl, and colesterol were applied to C.I.31A with a long hypodermic needle into the whorl area at the rate of 5 cc of solution per plant treated 3 times at 3-day intervals. Plants were dissected 10 days after egg hatch. Larval survival was 20 times greater on the "diet" treatment than on the distilled water.

B64 a yellow dent inbred tolerant to western corn rootworm developed cooperatively by USDA's Agricultural Research Service and Iowa Experiment Station was released to plant breeders in 1965.

Several hundred lines of corn were evaluated for corn rootworm resistance in South Dakota.

Laboratory techniques have been developed to test corn in the seedling stage for antibiosis to the larvae of the western corn rootworm. Evaluation is based on percent of original infestation recovered and size of recovered larvae after a given period. Differences have been observed based on the above criteria. Progeny tests are being conducted to evaluate these as potential sources of antibiosis.

Greenhouse tests with 36 inbred lines of corn revealed that three, R168, B55, and My3, posses a rather high degree of corn leaf aphid resistance.

Field cage studies at Tifton, Ga., showed that fewer earworm larvae could establish on unpollinated silks than on pollinated silks, indicating that either pollen itself, or the physiological or physical changes in silks initiated by fertilization helped larvae to become established.

Although slitting the husk of a resistant sweet inbred increased earworm damage, some factor or factors other than husk tightness contribute to resistance. Injury was not as great in resistant lines with slit husks as in susceptible inbreds with slit husks.

Six Southern Grain Insects Research Laboratory inbreds have indicated good resistance and quality in a hybrid testing program. Backcrosses of the inbreds in Walter's White have shown increased inbred vigor and maturation, yet little of the earworm resistance or quality has been sacrificed.

A feeding arrestant-stimulant obtained from lyophilized plant material was tested on filter paper for preference by larvae of the earworm, the fall armyworm, and the budworm. The response varied among the six species of plants tested, the plant portion used, and the species of insect. All three insect species preferred extracts of plant fruiting bodies to extracts of vegetative parts, indicating more arrestant in fruiting bodies. The feeding response was directly correlated to larval utilization and development, determined by incorporating plant material into diets. Utilization ranged from 12% to 61%.

A corn earworm larval feeding stimulant-arrestant extracted from corn kernels did not break down appreciably when stored dry at -10° C for 9 months. It does lose much of its effect when reconstituted and held at room temperature for 48 hours. The stimulant was still active after the extract was heated to 90° C for 5 minutes. Heating separated out the inactive water-suspended portion. In dilute form the extract is more effective as an arrestant than as a stimulant.

An olfactometer with an electronic system consisting of a scanner relay with a miniature proximity sensor was used to monitor adult corn earworm flight and oviposition responses to chemicals, especially extracts from corn plants. A chemical fraction in corn kernels has been found to act as an oviposition repellent but chemical extraction and stability has been difficult.

In Mississippi silks of corn hybrids rated as resistant, intermediate, and susceptible to the corn earworm were analyzed. Twenty amino acids among the protein samples were identified with little or no differences among the three types of corn. The non-protein samples showed that there were 22 in each class of silks and that the concentrations were lower in the resistant lines, slightly higher concentrations in the intermediate, with the highest concentrations in the susceptible lines of corn.

Determinations of reducing sugars in susceptible dent corn showed 22.53% present in fresh silks and 15.03% present in the resistant single cross.

In Mississippi 239 hybrids and varieties were rated for corn earworm damage. Embro Departure VIII, PAG Experimental 15307, Miss. 6133, Funk's G707, Dixie 18, McCurdy M306, Dixie 55, Coker 911, Coker 811A, Coker 67, Coker 71, and Embro 256 CP were the most resistant entries.

A husk extension of more than 2 inches and a silk channel diameter of less than 1 inch gave maximum mechanical protection against earworm injury.

Seven single cross tests involving 54 inbred lines showed that 11 inbreds, Mp462, Mp468, Mp464, Mp335, Mp1, Mp420, Mp426, F6, Mp313E, L501, and Ab18 had a high degree of earworm resistance.

In tests at Lafayette, Ind., there were 27 experimental hybrids more resistant than the most resistant commercial hybrids.

2. Small Grain and Sorghum Insects. At Tifton, Ga., eight varieties of barley commonly grown in the Southeastern United States were compared with each other for their relative ability to resist attack by four species of aphids. Length of life span of the female and the number of progeny were used as criteria of evaluation. The decreasing order of resistance of each variety to each species of aphid is as follows: The English grain aphid, Will, Gajet, Early Marconee, Davie, Davie X Harbine, Dayton, Colonial 2, and Rogers; the apple grain aphid, Will, Early Marconee, Rogers, Gajet, Colonial 2, Dayton, Davie, and Davie X Harbine; the greenbug, Robers, Davie, Dayton, Davie X Harbine, Gajet, Early Marconee, Will, and Colonial 2; the corn leaf aphid, Dayton, Early Marconee, Davie X Harbine, Gajet, Colonial 2, Davie, Rogers, and Will.

At Lafayette, Ind., barley selections were screened for corn leaf aphid resistance under greenhouse conditions. Two selections, CI 1267 and CI 1417, from the barley variety Squarehead and one selection, CI 1365, from the variety Bolivia appeared to be immune to corn leaf aphids. The nature of the resistance of these three barley selections seemed to be non-preference and possibly some antibiosis, since the aphids did not feed or reproduce on the selections.

Populations studies of the 4 races of Hessian fly have been continued in Indiana. Race B which is capable of infesting the W38 resistant wheats Monon, Redcoat, and Reed increased considerably in 1964-65. Races C and D which are capable of infesting Knox 62 have increased slightly. This increase in Hessian fly populations capable of infesting the presently available wheat varieties make it desirable to release wheats having the Ribiero source of resistance as soon as possible. Hessian fly populations continue to decline in Kansas and Nebraska probably due to the increased use of resistant wheats especially Ottawa.

Temperature above 70° F affects the expression of resistance in W38, PI94587, and Ribiero derivative wheats. The average percent of infestations for W38 derivative wheats at 60, 70, 80, and 90° F were 1.3, 4.0, 5.3, and 14.7 respectively. While PI94587 reacted resistant at all temperatures, its derivatives Knox 62 and Dular had an infestation of 14.0% at 90° F. Ribiero and its derivative 4217 were influenced by high temperatures, while the derivative 5273 had no infestation at any temperature level. Ribiero and 4217 had average infestations of 4.0, 9.0, 57.5, and 100% at 60, 70, 80, and 90° F respectively. Increasing temperatures also had an effect on larval survival in susceptible wheat plants. At 60, 70, 80, 90° F the average number of flax seeds found per plant were 49, 35, 24, and 2 respectively. High temperatures may be useful in screening for different sources and level of resistance. By infesting wheats at high temperatures those wheats having high sources of resistance may express themselves better than those having a low level of resistance.

At Lafayette, Ind., 24 F_2 families from crosses between 21 Chinese monosomics and the fly resistant variety Ribiero were evaluated for resistance to Race A.

Four chromosome families segregated in ratios that would be expected if the critical chromosome were involved, these being 2D, 4A, 6B, and 7A. Cytological investigation of the susceptible plants showed none to be nullisomic. This is contrary to what would be expected if the critical chromosome were involved and indicates the above chromosomes may not be involved.

Monon wheat heads from approximately 500 flag leaf infested with cereal leaf beetle and 500 uninfested were analyzed for kernel weight, kernel number, protein content, pearling index, mill yield, and water retaining capacity. Results indicated an estimated 25% yield reduction but there were no significant losses in wheat quality.

At Lafayette, Ind., Hessian fly resistant selections were obtained from back-cross lines involving Genesee and the Hessian fly resistant wheats Redcoat, 4217, and 4835. Approximately 3,000 head selections, hybrids or lines from the Purdue regular fly nursery, preliminary yield nursery, advanced yield nursery, fly stem nursery, and from previous fly tests were infested with greenhouse populations of 1 to 3 races of Hessian fly. All wheats have one or more of the W38, PI94587, Ribiero, and Marquillo resistances in their parentage. Many Hessian fly resistant winter type Ribiero and PI94587 selections were made. With a build up of Race B in certain areas in southern Indiana emphasis is being placed on breeding wheats having the Ribiero and PI94587 types of resistance or combinations of these with the W38 or Marquillo resistance.

The Triticum species collection (581 entries), the Sando collection (842 entries) and the spring wheat collection (1,870 entries) grown at Galien, Mich., for cereal leaf beetle evaluation were rated for Hessian fly resistance also. Under a heavy infestation of Hessian fly in the area, 193 entries reacted resistant to Hessian fly.

Two hundred and five Tennessee wheats were evaluated by Races A and B to determine the type of resistance involved in some of their breeding material with unknown pedigrees. All the lines that reacted resistant to Race A reacted susceptible to Race B indicating the W38 resistance to be present in their breeding material. Five hundred and forty-seven entries of new wheat introductions (PI268825 - PI288033) were tested to Race A. One hundred and eighteen that reacted resistant were retested to Race D to determine if the Ribiero or complete PI94587 resistances were involved. Eighty-six of the lines resistant to Race A also reacted resistant to Race D.

Several promising wheat stem sawfly spring wheats are in advance yield nurseries in North Dakota. The most resistant were selections 60-54, 51-3549 x II-50-17, 61-107, and (II-50-17 x 51-2688) ND4-Rescue. Studies in North Dakota showed that wheat stem sawfly sex ratio differ for resistant and non-resistant lines of spring wheat, as host plant resistance increased, the percent of male progeny also increased. Indirect evidence was obtained which indicates that the female adult sawfly can selectively oviposit fertilized or unfertilized eggs and that host plant stimulation encourages oviposition of fertilized or unfertilized eggs.

Over ten thousand small grain accessions were evaluated for cereal leaf beetle resistance in a field nursery in Galien, Mich. Seven hundred and forty-two of the wheat entries had none to a trace of larval feeding and were considered as resistant. None of the oat or barley entries were found to possess a high level of resistance, although some entries seemed to be less preferred. Laboratory tests utilizing adult feeding and egg-laying (both the total number of eggs laid and location of oviposition) as criteria for measuring host-plant resistance have shown that: (1) the pubescence of certain wheat plants acts as a deterrent to oviposition, (2) some wheat plants cause either a cessation of egg-laying or a substantial reduction in the number of eggs laid, and (3) adults were capable of feeding upon all plants tested.

One hundred entries of the preliminary yield and advanced yield nursery having Hessian fly resistance were evaluated for cereal leaf beetle resistance. Three entries from the preliminary yield nursery and one entry from the advanced yield nursery had light to intermediate feeding by the cereal leaf beetle under a heavy beetle infestation.

H. Insect Vectors of Diseases

1. Corn Insects. Cooperative research by State and Federal entomologists and pathologist have shown that the disease infecting corn in the South and Midwest since 1962 is due to two separate viruses. The one in the South is a persistent leafhopper transmitted virus known as corn stunt while the one in the Northern Area is a non-persistent virus now named maize dwarf mosaic and can be transmitted by aphids and also mechanically. There is evidence that the two diseases may overlap in Missouri and Arkansas. Cooperative research by State and Federal workers at Wooster, Ohio, established that the corn leaf aphid can transmit maize dwarf mosaic. At Tifton, Ga., Dalbulus maidis, a known vector of corn stunt disease, was collected on volunteer corn from August 25, until the first killing frost on November 15, 1964.

Under greenhouse conditions at Tifton, 138 transmission tests were attempted using leafhoppers, other than D. maidis collected from corn growing in fields with plants displaying symptoms of corn stunt disease. Eighteen genera and 22 species of leafhoppers were represented. No symptoms of corn stunt disease were observed in any test.

In Mississippi 33 species of leafhoppers were collected on corn during the 1964 growing season. D. maidis was collected in large numbers during the period August 18 to November 19, in Louisiana, Texas, and Mississippi. Corn stunt virus transmission trials were conducted with 8 common species of indigenous leafhoppers. Discolorations which were not typical corn stunt virus symptoms developed on corn following feeding trials with Graminella nigrifrons but no positive symptoms of corn stunt was observed.

At Tifton, Ga., studies were conducted on the developmental times for D. maidis, a known vector of corn stunt disease. At temperatures of 55° and 65° F eggs were not laid. At 75° F 5 days were spent in the egg and 15 days in nympal stadia. There was little difference in developmental times between 80°

and 90° F. The shortest developmental time observed was 12.5 days, with 2.5 days spent in the egg and 10 days in the nymphal stadia. The sex ratio of all reared progeny in all tests approached 1:1. The nymphs are rather quiescent and remain on the plants. Below 75° F the adults also tend to be quiescent, often found in the whorls, particularly of younger plants. The adults become very active at 80° and 90° F, flying readily from plant to plant. The temperature extremes that D. maidis can withstand are not known but tests indicate that it can survive over a range of at least 70° F. In a plant growth chamber one week survival was secured at a constant temperature of 102° F at both 50% and 80% relative humidity. Infested corn plants two weeks old were held at 32° F on three consecutive nights for 15 hours each and then returned to the growth chambers for observation. No mortality was noted and little, if any, effects were noted on subsequent development and reproduction potential.

Attempts to establish D. maidis on hosts other than corn in both growth chambers and in the greenhouse have been unsuccessful. These plants included several varieties of oats, wheat, barleys, rye, and sorghum. They can live and reproduce on Johnsongrass and gamagrass.

In connection with a research contract in Mississippi, a study was made of the predominant species of leafhoppers in the corn stunt area. Twenty-five different species were collected. G. nigrifrons was the most common species. Microlestes fascifrons was abundant in February and March, but was seldom collected in April and May, whereas the opposite was true of S. bicolor.

Research conducted in Israel under P. L. 480 project A10-ENT-5 on the rough dwarf virus disease of maize has shown that the virus can be maintained in the insect vector by transovorial passage to succeeding generations, even though the insects do not have access to host plants susceptible to the virus.

2. Small Grain Insects. At Brookings, S. D., barley yellow dwarf virus was transmitted by English grain and corn leaf aphids fed on extracts from infected barley using techniques previously developed for artificial feeding of the corn leaf aphid. Preliminary results have shown rate of centrifuging of crude plant extracts, acquisition feeding period, vigor of aphids, and population density of aphids in feeding cages are important influences on percent infectivity. The technique provides a useful tool for future basic investigations.

Studies on the effect of barley yellow dwarf on wheat yields indicated a reduction in winter wheat and 45% reduction in spring wheat.

Additional information on environmental conditions and techniques have permitted the testing of more than one hundred lines in the greenhouse for resistance to barley yellow dwarf virus. A few lines, mostly from New Zealand, have shown promise in maintaining productivity when infected with barley yellow dwarf.

The screening of more than 1800 lines of wheat for resistance or tolerance to barley yellow dwarf under field conditions, where healthy plots of each entry were grown adjacent to the diseased plots indicate that some lines possess resistance or tolerance to the virus or that they are symptomless carriers of the virus. Preliminary scorings of the entries show 1481 susceptible, 107 with mild symptoms, 209 with severe symptoms, and 14 with no symptoms.

At Manhattan, Kans., a migratory form of the wheat curl mite, the vector of wheat streak mosaic, has been observed in mite populations under laboratory and field conditions. These migratory forms are hardier, disperse more rapidly over plants, and distribute the eggs more widely than do the non-migratory mite forms. The dispersal of these migratory forms over wide areas when suitable hosts are present probably results in the development of infestations in epidemic proportions. Of all of the small grains, wheat continues to be the preferred host of the wheat curl mite.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Basic Biology, Physiology and Nutrition

Callahan, P. S. 1964. Basic semiconductor circuitry for ecological and behavioral studies of insects. USDA, ARS 33-94.

Callahan, P. S. 1964. An inexpensive actinometer for continuous field recording of moonlight, daylight, or low intensity evening light. J. Econ. Entomol. 57:758-60.

Callahan, P. S. 1965. A photoelectric-photographic analysis of flight behavior in the corn earworm, Heliothis zea, and other moths. Ann. Entomol. Soc. Amer. 58:159-69.

Callahan, P. S. 1965. Far Infra-red emission and detection by night-flying moths. Nature 206(4989):1172.

Castro, T. R., R. F. Ruppel, and M. S. Gomulinski. 1965. Natural history of the cereal leaf beetle in Michigan. Mich. State Univ. Agr. Exp. Sta. Quart. Bull. 47(4):623-53.

Chada, Harvey L., E. A. Wood, Jr., and Horace W. VanCleave. 1965. Yellow sugarcane aphid infestation and damage to small grains. Okla. Agr. Exp. Sta. Proc. Series P-492. 8 pp.

Cox, H C, K. J. Starks, and W. W. McMillian. 1964. Survey methods for corn insects damage in Southeastern United States. USDA Coop. Econ. Ins. Rept. 14(51):1299-1302.

Derr, R. F., and D. D. Randall. 1964. Trehalose: occurrence and relation to egg diapause and active transport in the differential grasshopper, Melanoplus differentialis. J. Ins. Physiol. 11:329-35.

George, Boyd W. 1963. Studies on the egg diapause of Diabrotica virgifera Lec. (Abstr.). Bull. Entomol. Soc. Amer. 9:108.

George, Boyd W., and Eldon E. Ortman. 1965. Rearing the western corn rootworm in the laboratory. J. Econ. Entomol. 58:375-77.

Hintz, A. M., and B. W. George. 1964. Studies on the development of Diabrotica virgifera Lec. (Abstr.). Entomol. Soc. Amer., No. Cent. Br. Proc. 19:93.

Jarvis, James L., and Tom A. Brindley. 1965. Predicting moth flight and oviposition of European corn borer by the use of temperature accumulations. J. Econ. Entomol. 58:300-302.

Raun, Earle S. 1964. Effects of refrigeration on corn borer egg hatch. Entomol. Soc. Amer., No. Cent. Br. Proc. 19:59-60.

Sisson, D. V., T. A. Brindley, and T. A. Bancroft. 1965. Combining biological data from European corn borer experiments over years. Iowa State J. Sci. 39(4):403-415.

Starks, K. J., W. W. McMillian, A. A. Sekul, and H C Cox. 1965. Corn earworm larval feeding response to corn silk and kernel extracts. Ann. Entomol. Soc. Amer. 58:74-6.

Wilson, M. C., and R. F. Ruppel. 1964. An overall look at the cereal leaf beetle crisis. Entomol. Soc. Amer. No. Cent. Br. Proc. 19:120-28.

Wood, E. A., Jr., and C. F. Henderson. 1965. Effect of greenbug control during jointing and booting stages of growth on yield of Triumph wheat. Okla. Agr. Exp. Sta. Proc. Series P-493. 4 pp.

Insecticidal and Cultural Control

Chada, Harvey L., C. F. Henderson, and Donald L. Bailey. 1965. Differential insecticide phytotoxicity in sorghum hybrids. Okla. Agr. Exp. Sta. Proc. Series P-491. 12 pp.

Chada, Harvey L., Donald L. Bailey, and R. R. Walton. 1965. Corn yield losses from southwestern corn borer infestation as related to harvesting methods. Okla. Agr. Exp. Sta. Proc. Series P-496. 8 pp.

Cox, H C, and M. C. Bowman. 1965. Uptake of fall armyworm larvae exposed to residues. J. Econ. Entomol. 58:87-92.

Hamilton, E. W. Aldrin resistance in corn rootworm beetles. J. Econ. Entomol. 58:296-300.

Henderson, C. F., H. G. Kinzer, and J. H. Hatchett. 1965. Effectiveness of insecticides against the corn earworm in sorghum heads. J. Econ. Entomol. 58:207-209.

Ruppel, R. F., and M. C. Wilson. 1964. Aerial applications of insecticides to control spring infestations of the cereal leaf beetle on small grains. J. Econ. Entomol. 57:899-902.

Ruppel, R. F., M. S. Gomulinski, D. L. Cobb, Y. M. Yun, and T. R. Castro. 1964. Tests of insecticides to control the cereal leaf beetle. Mich. State Univ. Agr. Exp. Sta. Quart. Bull. 47:259-70.

Ruppel, R. F., D. L. Cobb, and M. S. Gomulinski. 1965. Control of the cereal leaf beetle pupae. Mich. State Univ. Agr. Exp. Sta. Quart. Bull. 47:328-31.

Ruppel, R. F., and Y. M. Yun. 1965. Ground applied insecticides against the cereal leaf beetle. J. Econ. Entomol. 58:41-47.

Wilson, M. C., R. F. Ruppel, and R. E. Treece. 1965. Low volume concentrate sprays applied by aircraft for control of the cereal leaf beetle. J. Econ. Entomol. 58:11-14.

Yun, Y. M., and R. F. Ruppel. 1964. Toxicity of insecticides to a coccinellid predator of the cereal leaf beetle. J. Econ. Entomol. 57:835-37.

Yun, Y. M. and R. F. Ruppel. 1965. Laboratory studies of insecticides for control of the cereal leaf beetle. Mich. State Univ. Agr. Exp. Sta. Quart. Bull. 47:316-27.

Insecticide Residue Determinations

Fahey, Jack E., R. D. Jackson, and R. T. Murphy. 1964. Residues of organophosphorus insecticides found on corn plants treated for European corn borer control. Iowa State J. Sci. 39:153-60.

Fahey, Jack E., R. T. Murphy, and R. D. Jackson. 1965. Residues of chlorinated hydrocarbon insecticides found on corn plants treated for European corn borer control. Iowa State J. Sci. 39:437-47.

Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. Field evaluation of an electrostatic duster. J. Econ. Entomol. 58:71-74.

Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. DDT residues on sweet corn ear tips and silks after treatment with dust, spray, or granular formulations. J. Econ. Entomol. 58:55-58.

Jackson, R. D., Jack E. Fahey, and R. T. Murphy. 1965. Residues of carbamate insecticides on corn plants treated for European corn borer control. Iowa State J. Sci. 39:449-52.

Murphy, R. T., Jack E. Fahey, and R. D. Jackson. 1965. Residues from 1-Bromochlordene against European corn borer on corn. J. Econ. Entomol. 58:371-72.

Biological Control

Brooks, Derl L. and Earle S. Raun. 1965. Entomogenous fungi from corn insects in Iowa. J. Invert. Pathol. 7:79-81.

Insect Sterility, Attractants, and Other New Approaches to Control

Derr, R. F., D. Randall, and R. W. Kieckhefer. 1964. Feeding stimulant for western and northern corn rootworm adults. J. Econ. Entomol. 57:963-65.

Evaluation of Equipment for Insect Detection and Control

Hare, W. W., and E. A. Harrell. 1964. An experimental laboratory sprayer for simulating field conditions. USDA ARS 42-100.

Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. Field evaluation of an electrostatic duster. J. Econ. Entomol. 58:71-74.

Harrell, E. A., M. C. Bowman, and W. W. Hare. 1965. DDT residues on sweet corn ear tips and silks after treatment with dust, spray, or granular formulations. J. Econ. Entomol. 58:55-58.

Varietal Evaluation for Insect Resistance

Caldwell, R. M., L. E. Compton, F. L. Patterson, J. F. Schafer, R. L. Gallun, J. H. Hatchett, R. K. Stivers, O. W. Luetkemeier, M. J. Bitser, and S. Fonseca. 1965. Items from the United States - Indiana. 1964 Wheat Newsletter Vol. XI:49-52.

Everson, E. H., R. L. Gallun, and R. F. Ruppel. 1965. Items from the United States - Indiana. 1964 Wheat Newsletter Vol. XI:57-58.

Gallun, R. L. 1965. The Hessian fly. How to control it. USDA Leaflet No. 533. 8 pp.

Gallun, R. L., R. F. Ruppel, and E. H. Everson. 1964. Cereal leaf beetle resistance studies. Wheat News. 10:69.

Guthrie, W. D., E. J. Dollinger, and J. F. Stetson. 1965. Chromosome studies of the European corn borer, smartweed borer, and lotus borer (Pyralidae). Ann. Entomol. Soc. Amer. 58:100-105.

Knapp, J. L., P. A. Hedin, and W. A. Douglas. 1965. Amino acids and reducing sugars in silks of corn resistant or susceptible to corn earworm. Ann. Entomol. Soc. Amer. 58:401-402.

Ortman, Eldon E., and Paul J. Fitzgerald. 1964. Evaluation of corn inbreds for resistance to corn rootworm. (Abstr.) Entomol. Soc. Amer., No. Cent. Br. Proc. 19:92.

Pesho, G. R., F. F. Dicke, and S. W. Carter. 1964. Field comparisons of survival and damage of European corn borers from different egg mass sources. Entomol. Soc. Amer., No. Cent. Br. Proc. 19:88-91.

Scott, Gene E., Arnel R. Hallauer, and F. F. Dicke. 1964. Types of gene action conditioning resistance to European corn borer leaf feeding. Crop Sci. 4:603-606.

Shank, D. B., D. W. Beatty, P. J. Fitzgerald, and Eldon E. Ortman. 1965. SD 10 to combat. South Dakota Exp. Sta. Quart. Winter. pp. 4 and 6.

Insect Vectors of Diseases

Fitzgerald, P. J., and W. N. Stoner. 1965. Effects of various temperatures, photoperiods, and light intensities on yellow dwarf symptom expression in wheat. Crop Sci. 5:201-203.

Stoner, Warren N. 1964. Corn stunt and the leafhoppers Dalbulus maidis (DeL. & W.) and Dalbulus elimatus (Ball). (Abstr.) Entomol. Soc. Amer., No. Cent. Br., Proc. 19:99.

Stoner, Warren N. and A. J. Ullstrup. 1964. Corn stunt disease. Miss. State Univ. Agr. Exp. Sta. Info. Sheet 844. 4 pp.

Stoner, Warren N. 1964. Corn stunt disease in the United States through 1963. USDA Pl. Dis. Rep. 48:640-44.

Stoner, Warren N., Lansing E. Williams, and Leonard J. Alexander. 1964. Transmission by the corn leaf aphid, Rhopalosiphum maidis (Fitch) of a virus infecting corn in Ohio. Res. Circ. 136.

Stoner, Warren N. 1965. A review of corn stunt disease (Achaparramiento) and its insect vectors, with résumés of other virus diseases of maize. USDA ARS 33-99.

AREA NO. 8. RICE INSECTS

Problem. Several species of insects including leafhoppers, the rice stink bug, rice water weevil, grape colaspis, stalk borers, and the sugarcane beetle damage rice in the rice growing areas of the United States. Progress has been made toward the solution of some of the insect problems encountered in the production of rice but more effective, more economical, and safer insect control measures are needed. The appearance of resistance to certain insecticides in some rice insects stresses the need for basic information to overcome this problem. Additional emphasis should be given to new approaches to control rice insects and to evaluate rice varieties for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAM

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.6 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.5 to insecticidal control of rice stink bug and rice water weevil; 0.7 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 0.2 to insect vectors of hoja blanca and 0.2 to program leadership. In addition Federal support for research in this area provides for 0.4 man-year in a research grant to the University of Arkansas for varietal evaluation of rice for resistance to the rice water weevil.

PROGRAM FOR THE STATE EXPERIMENT STATIONS

Research on rice insects by the States is concerned with biology, ecology, and control. Studies are in progress which are designed to determine the economic importance of the various pest species present in growing rice. Efforts are being made to determine the amount of damage caused by different population levels of injurious species. Life history studies are under way which may reveal the vulnerable links in life cycles which can be exploited in control.

Information is being obtained on pest overwintering sites, spring emergence patterns, mating, egg deposition, length of developmental periods, food habits, number of generations per year, movement and dissemination and host relationships.

Biological and chemical control studies are being conducted in the field and laboratory to determine the most efficient and economical method for reducing damage. Rice samples from plots treated with insecticides are subjected to residue analyses.

There are 3.0 professional man-years dedicated by the States to research on insects affecting rice production.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Ecology, and Nutrition

Sperm were not transferred when male rice water weevils from Louisiana were mated with females from California. Weevils remained in a copulating position for 12 hours. Females that had been in copula for more than five minutes were dissected immediately after breaking copula and examined for the presence of sperm in the bursa copulatrix or spermatheca. A second group was dissected 24 hours after copulation. No sperm were found in either the bursa copulatrix or the spermatheca. Only female weevils have been found in California.

Rice water weevils confined on small rice plants in the laboratory at Baton Rouge, La., laid eggs in the leaf sheaths but none in the rice roots. Plants with eggs laid in the leaf sheath were also collected from the field at Crowley, La. The eggs were inserted paralleled to the plant fibers in the Perenchyma of the sheath, and the openings were plugged with a gelatinous substance. Egg deposition in sheaths usually occurred just below the water line.

The winter mortality of rice water weevils hibernating in grass clumps in Louisiana in 1964-65 was approximately 50%. None of the hibernating females examined in any of the samples contained sperm in the spermatheca.

An infestation of the lesser cornstalk borer, Elasmopalpus lignosellus was found in a rice field in Louisiana; this occurrence was the first record of this insect on rice in Louisiana. The infestation was controlled when the rice was flooded.

Sogata furcifera, a planthopper found on native grasses in Louisiana, lived an average of 16.5 days on healthy rice but 44.5 days on hoja blanca diseased rice, indicating that the hoja blanca virus is beneficial to this insect.

B. Insecticidal and Cultural Control

Seed treatments with UC-10854, UC-21149, Bayer 39007, Coumaphos, GS-13005, MCA-600, triphenyltin hydroxide, diazinon, SD-9129, aldrin, or an aldrin-heptachlor mixture did not provide adequate control of rice water weevil in a field experiment in Louisiana. Treatment with Bayer 39007 at rates of 1.0 and 0.5 pounds, SD 9129 at the rate of 0.5 pound and MCA-600 at the rate of 0.5 pound per 100 pounds of seed caused significant reduction in plant stand,

some of which was due to the interaction of the herbicide propanil used for weed control and these insecticides.

Aldrin applied at the rate of 0.25 pound per 100 pounds of seed failed to control water weevils at 5 of the 6 locations tested in Louisiana and Mississippi, indicating wide-spread occurrence of aldrin-resistant weevils in the southern rice-growing area.

Bayer 25141 applied as granules at the rate of 2 pounds toxicant per acre gave 80% control of rice water weevils. There was a significant increase in the number of rice water weevil larvae in plots treated with either phorate or Bidrin at the rate of 2 pounds toxicant per acre.

In a greenhouse experiment, carbaryl at 1 pound per acre gave a significant better reduction in egg hatch and nymphal survival of rice stink bugs over malathion applied at 5 pounds per acre.

Insecticidal seed treatment on rice, for control of rice water weevil, was evaluated for phytotoxicity in drill-seeded and water-seeded tests in the greenhouse. The insecticides were applied as an acetone solution of technical material. SD-9129 at 1.5 pounds per 100 pounds of seed, aldrin at 3 pounds, CL-52160 at 2 pounds, CL-47031 at 1.0 pound, B-44646 at 1.0 pound, and Di-Syston at 1 pound per 100 pounds of seed showed no phytotoxicity in drilled or water-seeded tests. Methyl parathion at 1 pound, parathion at 1 pound, GC-6506 at 0.5 pound, fenthion at 0.5 pound, Baygon at 0.5 pound, and triphenyltin hydroxide at 0.125 pound, were phytotoxic in water-seeded tests.

In a greenhouse test rice seed were treated at the equivalent of 0.75, 1.5, and 3.0 pounds toxicant per 100 pounds of seed with SD-9129, a phosphate insecticide with systemic capabilities. Germination was reduced at the 3.0 pound level. Nine days after planting, hoja blanca virus-infective adults of Sogota orizicola were caged on the plants. Six hours after caging, 69, 89, and 88% of the insects were dead in the respective concentrations, and 100% were dead at all treatment levels after 24 hours. Hoja blanca symptom development was reduced 63, 88, and 86% respectively indicating the insects had been killed prior to transmitting the virus to the rice plants. However, all treatment levels of the insecticide were ineffective 24 days after planting.

C. Varietal Evaluation for Insect Resistance

Seedlings of rice varieties vary in their attractiveness to Sogata orizicola. In greenhouse experiments, fewer insects were observed feeding on Nilo 1, Nilo 2, Chino, and Nato than on Bluebonnet-50, Gulf Rose, and Palo Gordo 503. Nilo 1 and Nilo 2 were most resistant to egg deposition and Gulf Rose was the most susceptible of 7 varieties tested.

D. Insect Vectors of Diseases

An experiment was run in cooperation with plant pathologists to determine if a

difference in transmission rate exists between acquisition periods of infective females starved for 48 hours and infective females held on Nato rice for 48 hours. The starved insects were allowed acquisition periods of 1, 2, and 3 hours with hourly transfers. The unstarved insects were allowed 1 hour acquisition. Very little transmission occurred at these acquisition periods and there were no differences between the periods or the two insect groups.

Eggs from viruliferous females were excised from leaf tissue, surface sterilized with 0.1% Hyamine solution, and placed into aseptic test tubes with aseptic rice seedlings growing in an agar medium containing a modified Hoagland and Knop solution. The tubes were placed in a temperature cabinet at 28°C. and under 14 hours illumination. After hatching, the nymphs were allowed to spend two days of the first instar on the seedlings, then were transferred to clean seedlings in aseptic tubes by vacuum through a sterile 27 gage needle. The nymphs adhered to the tip of the needle, and dropped off upon the termination of the vacuum. Disease symptoms were observed on two seedlings that had been used only during the first instar. This indicates that S. orizicola may receive the virus transovarially, and can feed and transmit the virus as first instar nymphs.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Insecticidal Control

Everett, T. R., and W. B. Showers. 1965. Effects of aldrin formulation and methods of seed treatment and planting on rice water weevil control. 56th Ann. Prog. Rep. of the Louisiana Rice Exp. Sta. pp. 238-239.

Everett, T. R., R. D. Hendrick, and W. B. Showers. 1965. Rice water weevil resistance to aldrin insecticide. 56th Ann. Prog. Rep. of the Louisiana Rice Exp. Sta. pp. 240-243.

Everett, T. R., and W. B. Showers. 1965. Insecticidal control of rice water weevils. 56th Ann. Prog. Rep. of the Louisiana Rice Exp. Sta. pp. 244-249.

Showers, W. B., and T. R. Everett. 1965. Insecticidal control of rice stink bug. 56th Ann. Prog. Rep. of the Louisiana Rice Exp. Sta. pp. 250-253.

Hendrick, R. D. 1965. Some effects of insecticides on the production of Louisiana red crawfish in rice fields. 56th Ann. Prog. Rep. of the Louisiana Rice Exp. Sta. pp. 254-255.

Insect Vectors of Diseases

Hendrick, R. D., T. R. Everett, H. A. Lamey, and W. B. Showers. 1965. An improved method of selecting and breeding for active vectors of hoja blanca virus. J. Econ. Entomol. 58:539-542.

AREA NO. 9. COTTON INSECTS

Problem. Insects are major deterrants to economical production of cotton and their control is a major cost factor in the production of the crop. Although present insecticide control measures for various cotton pests have been effective enough to keep growers in the cotton production business, they leave much to be desired from the standpoint of safety, efficiency, and undesirable residues. The development of resistance to certain insecticides in 20 cotton pests emphasizes the need for basic information on ways to solve or avoid the problem and to develop other methods of control that are more effective, economical and desirable. An inbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed on cotton. More research on approaches to control such as sterile male or female techniques, repellents, cotton varieties resistant to insects, biological control agents, safer insecticides, more effective ways of applying them, and chemically induced plant resistance to insect attack is needed to develop improved methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. A boll weevil found attacking cotton in northwestern Mexico and in Arizona is posing a threat to cotton production in New Mexico and California where it does not now occur. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance. Such knowledge could serve as a basis for advising growers when control measures for the various pests will or will not be required.

USDA AND COOPERATIVE PROGRAM

Research on cotton insects is conducted at field laboratories located at Florence, S. C.; State College, Miss. with satellites at Stoneville, Miss. and Tallulah, La.; Baton Rouge, La.; College Station, Tex.; Brownsville, Tex. with a satellite at Waco; and Tucson, Ariz. with a satellite at Tempe.

Various aspects of research being conducted are as follows: (1) studies of ecological factors which affect population dynamics, damage, distribution, life histories, survival and dispersal of various cotton pests in different areas; (2) basic research on the physiological processes and biochemical requirements in the normal metabolism of such insects as the boll weevil, bollworm, tobacco budworm, pink bollworm, cabbage looper, beet armyworm and salt-marsh caterpillar to develop improvements in procedures for mass rearing; (3) studies to determine the mode of action and fate of various chemicals in and on such insects as the bollworms and boll weevil and to determine the mechanisms by which the insects are able to develop resistance to insecticides; (4) studies to discover and develop more effective conventional and systemic insecticides and to improve methods of application

to increase their efficiency in controlling various cotton pests; (5) research to discover and develop methods of using pathogens or other biological agents to control the boll weevil, bollworm, tobacco budworm, cabbage looper and other cotton pests; (6) studies to discover and develop cotton varieties resistant to or tolerant of attacks of such pests as the bollworm, tobacco budworm, cabbage looper, pink bollworm, boll weevil, cotton fleahopper, cotton aphid and spider mites; (7) research to develop the sterile-insect technique and procedures for using it alone or in combination with other methods for controlling or eradicating the boll weevil and pink bollworm; (8) studies to develop practical methods of employing biologically active compounds, attractant, feeding stimulant, and repellent, of the cotton plant, and sex attractants for controlling cotton insects; and (9) development or improvement of equipment for insect control such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill equipment, light traps, and ultrasonic and electronic equipment.

The research is conducted in cooperation with the Agricultural Experiment Stations of South Carolina, Mississippi, Louisiana, Texas and Arizona and with the Plant Pest Control, Crops Research, Soil and Water Conservation, and Agricultural Engineering Research Divisions. Research is also supported by grants, contracts or cooperative agreements with Texas, Mississippi and California Agricultural Experiment Stations and the Southern Research Institute.

The Federal Scientific effort devoted to cotton insects research totals 67.8 professional man years. Of this number 24 are devoted to basic biology, physiology and nutrition; 18 to insecticidal and cultural control; 5 to biological control; 12 to insect sterility, attractants and other new approaches to control; 1 to evaluation of equipment for detection and control; 4 to varietal evaluation for insect resistance; 0.8 to insecticide residue determinations; and 3 to program leadership:

In addition Federal support for 1.8 man-years of research in this area is provided in contracts and grants. Of this total 0.9 is devoted to basic biology, physiology and nutrition; 0.6 to biological control; and 0.3 to insect sterility attractants and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research programs on cotton insects are conducted by the major cotton-producing states. Information is being obtained on the ecological factors responsible for rapid population increases of pest insects as a basis for accurate forecasting of destructive outbreaks. Variations in insect numbers and behavior through hibernation, spring emergence, summer development and diapause are being determined. Laboratory studies are under way to learn what factors are responsible for initiation of diapause in the boll weevil, pink bollworm and cotton bollworm. Emphasis is being

placed on the influence of light, nutrition and temperature. Other studies are concerned with the influence of chemosterilants and radiation on reproductive physiology. Laboratory rearing techniques, using artificial lights, are being developed to provide insects for year-round study, and to determine the effects of varying concentrations of nutrients in the diet.

Biological information is being assembled on rates and characterization of developmental stages, rate of egg deposition, mating habits, longevity and mortality.

Cultural control studies include the influence of varying fertilizer levels on infestation size, the benefits obtained from crop residue destruction in the fall, and the development of varietal resistance. Research in the latter area consists of screening introduced plants for resistance, crossing them and selecting progeny which exhibit useful traits. Biological, physiological and chemical studies are conducted to determine the factors responsible for resistance.

Chemical control studies include the evaluation of new materials with particular emphasis on systemic insecticides. Research includes basic mode of action studies in insects and the metabolism of systemic insecticides in the cotton plant. Various methods of application are being evaluated for field use.

The total State scientific effort devoted to cotton insect research is 53.8 professional man years.

PROGRESS--USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Boll Weevil. Two stub cotton fields in Pinal and Yuma counties, Arizona, were found infested in June, 1964. The infestation became heavy by the end of August. The yield loss was estimated to be $1\frac{1}{4}$ bales in the Pinal County field and $1\frac{1}{2}$ bales per acre in the Yuma County field.

Crosses of F_1 and F_2 progeny from Caborca, Mexico weevil and Tucson thurberia weevil crosses produced progeny in studies at Tucson, Arizona. Caborca by thurberia females crosses with thurberia by Caborca males laid an egg from which an adult was reared. Two females from crosses of F_2 progeny laid viable eggs. These results indicate that the weevils in Caborca, Mexico cotton are the same species as the thurberia weevils in Tucson, Ariz.

In laboratory studies at Tucson, Arizona hybrid females from crosses of Caborca, Sonora and Tucson thurberia weevils produced viable eggs for as long as 3 months after mating. Four thurberia-cotton hybrid females which had been mated with male thurberia weevils produced viable eggs 7, 13, 52, and 95 days after the removal of the male, and six cotton-thurberia hybrid females laid fertile eggs for 13, 15, 25, 38, 42, and 96 days after separation from the males. In these tests the laying of viable eggs was limited only by the insects' longevity.

High boll weevil survival in old bolls was indicated for a Yuma County, Arizona field that grew stub cotton in 1964. The stalks had been destroyed with a shredder. Boll inspections made on February 9, 1965 in this field showed an average of 1254 live adult weevils per acre. Boll weevils emerging from ground trash in hibernation cages on March 15 in Pima and Pinal Counties, Arizona indicated that they are able to overwinter outside the boll from one crop year to the next. Thurberia weevils have been known to overwinter only in bolls.

A live female thurberia weevil was removed from a thurberia boll which had been held in storage for 17 months at State College, Miss. She lived for two months thereafter and laid 151 eggs.

Boll weevil survival in the spring of 1965 was higher than in 1964 in all areas. Spring woods-trash examinations for hibernating boll weevils were made in central Texas, northeast Louisiana, Delta and Hill sections of Mississippi and in three areas in the Carolinas. Comparative survival since 1960 in the various areas was as follows:

	Weevils Per Acre				
Area	1961	1962	1963	1964	1965
Central Texas	1516	1361	452	97	4925
Northeast Louisiana	2193	2233	121	1049	3052
Mississippi	1246	1132	13	289	995
South Central South Carolina	376	1667	914	753	1855
Coastal Plains, N.C. & S.C.	1129	3654	1560	2742	10164
North Central North Carolina	430	968	161	107	1371

Boll weevil survival in 1965 was greater than the previous 4 years except in Mississippi where survival was slightly higher in 1961 and 1962. Survival in the coastal plains of the Carolinas was especially high. At Florence the number surviving was greater than in any year since records were made beginning in 1938.

At Tucson, one boll weevil emerged in the spring of 1965 from 27 gallons of green bolls collected in November, 1964 and installed on the soil surface in hibernation cages. Three weevils emerged from 21 gallons of green bolls installed in cages 6 inches above the ground on screens. Two weevils emerged from 100 pounds of bolls which were collected in early March from standing stalks in 3 fields in the area and installed in 6 hibernation cages. However, at Florence, S. C., boll weevils in green cotton bolls when the plants were killed by freezing temperatures failed to survive the winter. The infested bolls were held in the insectary, on the soil surface, above the soil surface, and on standing stalks in the field.

Egg deposition after October 1 does not contribute to the overwintering boll weevil population at State College, Mississippi. In this study of the fall biology of the boll weevil, eggs laid after October 1 did not contribute to the overwintering population. Eggs deposited during early to mid-September produced adults which emerged throughout October and early November.

The Texas A & M strain of boll weevils used in the mass rearing program at the State College, Mississippi laboratory appears to be non-diapausing. In laboratory experiments 11-hour photoperiod in larval and pupal stages, boll feeding in adult stage, limited number of squares made available in adult stage, and low night temperatures in adult stage did not induce diapause in this strain of weevils. A Mississippi wild strain held under identical conditions developed diapause.

Pink adult weevils were reared on larval diet containing dye at State College, Miss. The adults retained color for 8 weeks and females laid pink eggs. A calco oil red was the best of several dyes tested.

The boll weevil synthetic diet was modified at Florence, S. C. Additional tests have shown that a reduced amount of methyl parasept and potassium sorbate can be used to reduce contamination in adult laboratory boll weevil diets. This reduced amount is effective for at least 24 hours and does not significantly reduce egg production, hatch, or yields of adults.

In replicated laboratory tests at Florence, S. C. boll weevils oviposited at a higher rate on the synthetic diet containing egg albumin than on the diet containing cotton squares.

The pH of the mid-gut of boll weevil larvae was determined at State College, Miss. from larvae immediately after they were removed from artificial diet and from those starved 2 to 4 hours. The mid-gut was divided into the anterior (crop) and posterior regions for the analyses. The crop region had pH of about 5.8-6.1, and the posterior portion 7.1-7.6.

In studies at State College, Miss. free amino acids found in boll weevil pupae were cysteic, taurine, aspartic, threonine, serine, glutamic, proline, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, aminoisobutyric, lysine, histidine and arginine.

Physiological disposition of C^{14} tepa in the boll weevil was determined in studies at State College, Miss. Tepa has a biological half-life of 6 hours, is preferentially picked up by the foregut and gonads, is poorly absorbed through the integument and reaches its peak in the blood of the boll weevil in 90-100 minutes.

In studies at Baton Rouge, La. acetate-1-C^{14} injected into adult boll weevils undergoes immediate oxidative metabolism with the subsequent release of $C^{14}O_2$. Maximum $C^{14}O_2$ production is reached one hour after injection at which point about 25% of the injected acetate has been converted to CO_2. Thereafter the release rate declines steadily. By 12 hours, 50% of the injected C^{14} has appeared as respiratory $C^{14}O_2$.

Boll weevil larvae synthesized long chain fatty acids from isotopically labeled acetate in their diet in studies at Baton Rouge, La. Oleic acid was the principal acid synthesized along with lesser amounts of palmitic, palmitoleic, stearic, and linolenic. Like the adult, the larvae does not synthesize linoleic acid. The amounts synthesized and labeling pattern were almost identical when C^{14}-1- and C^{14}-2-acetate were used as the precursors.

In studies at Baton Rouge, La. the boll weevil absorbed some fatty acids in its diet and stored them unchanged but modified the remainder to form other types of fatty acids. Labeled palmitic acid may be changed to palmitoleic by desaturation, or its chain may be elongated by two carbon atoms to stearic, which in turn may be desaturated to oleic. However, if labeled stearic acid is placed in the diet, it is absorbed unchanged or desaturated to oleic, and very little is shortened to form palmitic acid. If labeled oleic is used, it is absorbed primarily as oleic and neither the saturation or shortening pathways operate to any appreciable extent. The boll weevil larva cannot convert closely related dietary fatty acids to linoleic acid. Very little labeling of the linoleic fraction is found in body fat from weevils fed on tagged stearic and oleic acids. The slight counts in linoleic acid can be due to carryover from the highly radioactive oleic acid fraction.

In studies at Baton Rouge, La. diapausing boll weevils contained more total sterols than reproducing weevils. The greatest difference occurred in the sterol ester fraction, especially in the females. Two week-old diapausing females contained an average of 58 micrograms of sterol, over one-half of which was esterified. It is possible that this relatively large amount of sterol ester could contribute to the observed tolerance of diapausing weevils to chlorinated hydrocarbon insecticides.

At Baton Rouge, La. analyses of feces from weevils fed a diet containing C^{14}-cholesterol showed large amounts of unidentified polar steroids. The percentage of the total radioactivity present in the polar fraction ranged from 36 to 53%. Thus, it appeared that the boll weevil metabolized a substantial portion of its sterol before it was excreted. In contrast, the sterols in the eggs were almost entirely in the free sterol and sterol ester forms with only a trace of polar steroids.

In studies at Baton Rouge, La. crude extractable lipids accounted for almost 11% of the wet weight of 10-day-old adult boll weevils fed cellucotton moistened with 20% sucrose. If the boll weevil is unable to digest cellulose, these results indicate that sucrose is converted to lipid in the weevil and supports the theory that the higher titer of sugars in bolls than in squares is responsible for the accumulation of glycogen and triglycerides in boll-fed weevils.

Trehalose and glucose levels were determined in eggs and papae of boll weevil at Baton Rouge, La. Both trehalose and glucose were present in the pupae but the titer of trehalose was only slightly higher than that of glucose. During the pupal period the levels of trehalose and glucose decreased from about 90 to 100 micrograms to about 30 to 45 micrograms per insect. Boll weevil eggs contained both trehalose and glucose, but the quantity of trehalose (2.78% of the dry weight) was considerably greater than the quantity of glucose (about 0.25% of the dry weight).

The rate of elimination of sterols by adult boll weevils was studied with C^{14}-tagged cholesterol at Baton Rouge, La. Weevils reared from larval diet containing 4-C^{14} cholesterol were sacrificed after feeding on untagged adult diet for 0, 1, 2, and 3 weeks. At the end of 3 weeks, the weevils had lost 70 to 80% of the original radioactivity. The females esterified the cholesterol a little more rapidly and lost slightly more radio-activity than the males.

Mutant strains of boll weevils were used to determine mating and reproduction patterns of females in studies at State College, Miss. Experiments showed that sperm mixing takes place when a female is mated with two different males but the second mating produced most of the progeny.

An all black strain of boll weevils has been developed at Florence, S. C. A small colony of these weevils is being maintained in the laboratory for use in future field studies.

Cholinesterase activity of boll weevils fed chronic sublethal or lethal doses of Bidrin was determined in studies at College Station, Texas. Adult boll weevils fed chronic doses of Bidrin had an initial cholinesterase decline and then a recovery to near normal. This indicates a secondary cause of death (other than ChE inhibition) in insects treated with organophosphorus insecticides or that only a small fraction of the total cholinesterase at a vital site is directly associated with death.

Boll weevil susceptibility to toxaphene is affected by lipid composition of the diet. Additional tests confirmed that weevils reared on diets containing a mixture of cottonseed-linseed oils (1:1) were less susceptible to toxaphene than those fed on a diet containing either cottonseed or linseed oils alone.

A strain of boll weevils resistant to chlorinated hydrocarbon insecticides reared on a fat-deficient diet in the laboratory at Baton Rouge continued to be highly resistant to endrin. There was a further increase in the resistance level of weevils reared on this diet when triolein was added in amounts as low as 50 mg per 100 g of diet.

In studies at Baton Rouge, La. the molecular weight of boll weevil glycogen extracted from larvae with cold water was much higher than that extracted with trichloroacetic acid. The sedimentation curves from the Spinco Model E ultracentrifuge showed two regions of different molecular weight.

The lower molecular weight component appeared at 150-200 svedbergs and the higher molecular weight material appeared at 900-1200 svedbergs. When larval glycogen was extracted with trichloroacetic the higher molecular weight component was completely destroyed, and the quantity of the lower molecular weight was increased.

In studies at Baton Rouge, La. the boll weevil synthesized long chain fatty acids from glucose-1-C^{14} in its larval diet. Palmitic and oleic acids accounted for nearly 70% of the C^{14} incorporated as fatty acid. The labelling pattern was quite similar to that obtained when the larvae are reared on a diet containing C^{14} acetate.

In studies at Baton Rouge, La. triglycerides, the dominant lipid constituents, made up 70% by weight of the lipid matter in boll weevil egg yolk. Sterol esters and sterols accounted for about 12% of the lipids, and free fatty acids for about 6%. The egg lipids were fractionated by a two-phase column chromatographic technique, and each fraction was checked by TLC. Triglyceride fatty acids of the boll weevil egg have a different spectrum than those of body fat. Linoleic acid (along with palmitic) replaces oleic as one of the two largest components. The free fatty acid fraction of eggs is somewhat similar to triglycerides but contains a larger titer of short chain components and lesser amounts of palmitic and linoleic acids.

In studies at Baton Rouge, La. the sugar content of the thurberi boll was found to be slightly lower than that of the cotton boll. Sugars account for about 10% of the dry weight of the thurberi boll. The two main sugars are glucose and fructose. The titer of sugars is higher in the larger bolls. The high sugar level is probably a very important

factor leading to the accumulation of carbohydrate and lipid reserves which probably enables the thurberia weevil to survive the winter in the thurberi boll.

In studies at Baton Rouge, La. weevils in diapause utilized palmitic and oleic acids at an even rate, but reproducing adults used more oleic acid than palmitic acid. The oleic:palmitic ratio remained unchanged at about 1.72 in weevils in diapause for 6 months, whereas in reproducing adults it dropped to 1.33 indicating a relative and selective decrease in oleic acid.

Boll weevil egg production was reduced at Baton Rouge, La. unless linoleic acid was available during larval stage. A fatty acid deficiency during the larval stage of either sex reduced the numbers of eggs produced. The larvae needed only very small amounts of polyunsaturated fatty acids. Linoleic and linolenic acids carried over from the parent generation through the egg satisfied the essential fatty acid requirements of the larvae. Although weevils could synthesize a large amount of oleic acid, they still laid more eggs in diet containing triolein as the only source of fatty acids. Gas chromatographic analyses showed that adults maintained on a fat-deficient diet contained significant amounts of linoleic acid. Some synthesis of this acid was indicated, since the trace amounts found in the larval diet were present at a much lower concentration. It was not possible to demonstrate a dietary requirement for vitamin E. Weevils maintained for three generations on diets containing no added vitamin E continued to lay large numbers of eggs.

In studies at State College, Miss. no linkage was found between two previously described genetic markers in the boll weevil. F_2 data indicated no linkage between the eye marker designated pearl, and the body marker, ebony.

Ground and aerial application of a blue enamel to cotton marked up to 38% of the boll weevil population in State College, Miss. and Tallulah, La. Yellow was inferior to the blue and the airplane applications appeared to be superior to ground sprayer applications. This technique should be of value in a number of boll weevil field studies.

A more efficient method of implanting eggs on larval media was developed at State College, Miss. Boll weevil eggs were suspended in a solution of 20 g. sucrose, 2 g. cornstarch and 100 g. water. The suspension was sprayed onto the roughened surface of the larval media.

In tests at State College, Miss. boll weevil eggs were not adversely affected by saturated salt solutions and strong acids. Eggs soaked over 72 hours in saturated copper sulfate and other salts hatched normally. Fifty percent phosphoric acid, 40% sulfuric acid and 20% nitric acid for 72 hours failed to destroy the eggs. Organic acids were toxic at very low concentrations. Sorbic acid was over 200 times as toxic to the eggs as potassium sorbate.

Metabolism studies of SD-9129-P^{32} in cotton plants at College Station, Texas indicated a metabolic route similar to that of Bidrin. An unknown metabolite in aged SD-9129 residues appears very similar to the Bidrin unknown. There is evidence that hydroxy-methyl Bidrin is a precursor to the Bidrin unknown.

The systemic activity of Di-Syston-P^{32} was determined in studies at College Station, Texas. Soil type influenced uptake of Di-Syston by cotton plants when the toxicant was applied in the soil. Much larger amounts of Di-Syston were recovered from plants growing in light soil than in heavy soil. Seed treatment tests indicated that larger amounts of Di-Syston were taken up by plants grown from acid delinted seed than from mechanically delinted seed.

Studies at College Station, Texas showed that Shell SD-9129 was translocated to nectar in cotton plants. In tests with SD-9129-P^{32} applied to cotton plants, significant quantities of the original compound was recovered in the nectar.

2. Bollworms. In 1964 studies of Heliothis spp. on cotton at Brownsville, Tex. showed H. virescens had 4 population peaks while H. zea had only two. Highest populations of H. zea were in the first peak (June 5-12) while that of H. virescens was in the last peak (August 7-14). The first peak of H. zea seems to be related to corn maturity. At waco, Tex. only 7.4% of larvae collected on cotton during the season were tobacco budworms. This compares with 46% in 1963. At Stoneville, Miss., 10.5% of the larvae collected on cotton during the season were tobacco budworms, ranging from 35.5% in June to 4.5% in September. Eight percent of bollworm larvae collected on cotton at Tallulah, La. were tobacco budworms.

Heliothis virescens was collected on Indian paintbrush at Waco, Texas. Determinations of 222 bollworm larvae collected from 6 different early-season host plants during April and May, 1965, showed that 215 were H. zea (Boddie) and 7 were H. virescens (F.). All of the H. virescens were collected on Indian paintbrush. Although only two tobacco budworm moths were collected in the light trap, 90% of the larvae collected on cotton in June were determined as the tobacco budworm.

The tobacco budworm was the predominant Heliothis sp. on cotton early in the season at Stoneville, Mississippi. Eggs were collected in the field and larvae reared from them. Over 60% were tobacco budworms, 30% bollworms, and the remainder loopers and cutworms. Alfalfa appeared to be the preferred host of the bollworm early in the season. At Tallulah, Louisiana, the number of the 2 species of cotton was about the same.

3. Pink bollworm. One hundred twenty-five live and 50 dead pink bollworm larvae were found in 5 pounds of bolls collected from standing stalks in March, 1965 near Waco, Texas. Survival and moth emergence from this material in May and June was heavy.

Studies at Brownsville, Texas show that pink bollworms may be disseminated in okra shipments. Fancy and choice graded okra, totaling 70 bushels, was obtained periodically from packing sheds in Cameron County during the period April 22--June 15 and caged outdoors for moth emergence. One pink bollworm moth emerged on May 17 from okra collected April 15.

4. Other Insects. Infestation of lygus bugs in cotton in the early fruiting stage reduced yield at first picking up to 50%. In field cage tests introductions of 1 tarnished plant bug adult per plant per week for 3 weeks just prior to or during early squaring stage reduced the yield of seed cotton at the first picking as much as 50% when compared with uninfested cotton.

Incubation time required for lygus bug eggs held at different temperatures in the laboratory at Tucson, Arizona provided formula useful in predicting time of egg hatch. The duration of the egg stage of Lygus hesperus at seven different temperatures suggested that 10° C. lies below the developmental threshold and that 40° C. lies above the limit at which hatching can occur. The data were used to calculate a regression equation which was converted into a formula $y, = \frac{1000}{-77 + 8.06\ X}$.

In studies at Tucson, Arizona salt-marsh caterpillar moths deprived of water or food laid a higher percentage of fertile eggs than fed moths. Moths fed 5 percent sugar solution laid an average of 1,111.5 eggs per mating pair, those fed distilled water 776.7, and those given no food or water 437.5. Comparative fertility of eggs laid by moths fed only water, those fed 5% sugar solution, and those unfed was 20.7%, 42.4% and 65.3%, respectively.

Lygus hesperus is predominant plant bug species in the spring in Arizona. Sweep net sampling of 33 alfalfa fields at bi-weekly intervals from April 20 to May 26, 1965, in the Yuma to Phoenix area totaled 3449 Lygus hesperus, 492 L. elisus and 36 L. lineolaris. Numbers in the above area per net sweep were more than twice that of the St. David to Safford Area.

B. Insecticidal Control.

1. Boll Weevil. The effectiveness of technical malathion applied at rates of 9.0, 9.6 and 12.8 fluid ounces per acre, 11.0, 11.7 and 15.7 ounces by weight, respectively, was evaluated against boll weevils near Afton, Dickens County, Tex. When weevils were caged on plants immediately after treatment, kills after 24 and 48 hours in the plot treated with 12.8 fluid ounces in 75 foot swaths were 98 and 100%. In the plot treated with 9.6 fluid ounces in 100 foot swaths, kills after 24, 48, and 96 hours were 68, 82, and 100%. In another test kills after 24 and 48 hours in a plot treated with 9.6 fluid ounces in 100 foot swaths were 82 and 98%. In a plot treated with 9 ounces in 75-foot swaths kills were 90 and 100%.

A replicated test was conducted at Tallulah, La. in which 16, 12, and 8 fluid ounces of technical malathion, 20, 15, and 10 ounces by weight, respectively, were compared with methyl parathion applied at 0.25 to 0.5 pound per acre in an emulsion. Infestation records indicated that there was no appreciable difference in control obtained with the various dosages of malathion, and control obtained with them compared favorably with that obtained with methyl parathion.

Malathion diapause treatments reduced overwintering boll weevil populations in Sonora, Mexico. Ground trash examinations in January showed that treatments of 10 and 16 fluid ounces of technical malathion per acre reduced populations by 60 and 90 percent, respectively, compared with populations in untreated fields at Caborca.

Overwintered boll weevil populations were reduced at Tallulah, Louisiana by ultra low volume applications of technical malathion in the fall. The average number of weevils per acre in June, 1965, in fields receiving various treatments last fall were as follows: malathion at 12 ounces 7 weevils; malathion at 16 ounces 5 weevils; methyl parathion at 0.5 pound per acre in a conventional spray 5 weevils; and untreated check 130 weevils per acre.

From studies at State College, Miss. it is hypothesized that surfactants are partially responsible for formulated malathion being less effective than the undiluted technical material. In a project to investigate the influence of surfactant structure and concentration on toxicity of malathion, plans to topically apply undiluted technical insecticides have been cancelled. Volumes of 0.0008 and 0.000,05 microliters of undiluted technical malathion and methyl parathion would produce 50% mortality if applied topically to the boll weevil. Volumes of less than 0.005 microliters can not be delivered reproducibly with present equipment.

Boll weevil populations did not reach damaging numbers until the second field generation in a Carroll County, Miss., diapause control experiment. Fall treatments in 1963 consisted of six applications of methyl parathion spray at 0.5 lb. per acre at 4- or 5-day intervals, plus defoliation and three selected follow-up treatments. Overwintered weevils in 1964 were estimated at 4.3, 2.7 and 26.0 per acre in the three diapause control treated fields. In two fields where diapausing weevils were not controlled, populations were estimated at 13 and 52 per acre prior to application of early-season insecticide treatments. Boll weevil control was not needed in the fall-treated fields until August 12, 1964.

In tests at Florence, S. C. in 1964 a granular formulation of candidate systemic insecticide, Union Carbide UC-21149 was effective against boll weevils at high rates. When UC-21149 was applied to cotton as a side-dressing at rates of up to 32 pounds per acre, it gave significant mortality of boll weevil adults feeding on squares and of boll weevil larvae

developing in squares and bolls. When applied just before cotton plants began to square, UC-21149 at 6.8 pounds per acre caused significant mortality of adults feeding on foliage and squares, and larvae developing inside squares for at least 3 weeks.

At College Station, Texas cotton stem and soil treatments with systemic insecticides were effective in greenhouse tests against boll weevils. In stem treatment tests Union Carbide UC-21149 and American Cyanamid CL-47031 were the most effective compounds. In soil treatment tests Union Carbide UC-21149 was the most active compound but it caused considerable phytotoxicity. Union Carbide UC-21149 applied to the soil was found in leaves, squares and square bracts of cotton plants grown in it. Boll weevil bioassay of various parts of cotton plants grown in the greenhouse in soil containing UC-21149 showed that the highest concentrations of the toxicant were in the leaves with significant amounts in the squares and square bracts. Candidate systemic insecticide, American Cyanamid CL-47031, applied as a stem treatment showed promise against boll weevils. The insecticide applied with a tractor mounted brush applicator gave better control than when it was applied with a lateral spray applicator.

A standard test procedure has been developed at State College, Miss. in which 0.007 to 0.056 microliter doses are applied topically to the adult boll weevil for screening candidate insecticides. Of sixteen compounds screened six had LD-50's between malathion and methyl parathion and the remaining ten had LD-50's greater than 1 microgram per weevil.

In small plot replicated tests at Stoneville, Miss. in 1964, 1 pound-per-acre dosages of General Chemical GC-9160, Mobil MC-A-600, EPN, Geigy 12968 and 13005, and Bayer 44646, and 0.5-pound dosages of Niagara 10242 and Shell SD-9129 were as effective as such standard materials as 0.25 pound of Guthion plus 1.0 pound of DDT or 2 pounds of toxaphene plus 1.0 pound of DDT per acre. A mixture of 1.5 pounds of carbaryl plus 0.75 pound of UC 10854 gave better control than carbaryl at 2.0 pounds per acre. A mixture of 2 pounds of toxaphene plus 1.0 pound of DDT plus 0.25 pound of dioxathion was more effective than the mixture without dioxathion.

2. Bollworms. Several insecticides were effective against bollworms in field tests. In one experiment at Waco, Tex. there was no difference in control obtained with the following materials: Bayer 44646 at 2.0 pounds; Shell SD 9129 at 0.5 and 1.0 pound; Shell SD-8447 at 1.0 pound; and toxaphene at 2 pounds plus DDT at 1.0 lb. per acre. In another experiment Mobil MC-A-600 at 2 pounds and a polyhedra virus at 100 diseased larvae per acre gave control of a light bollworm infestation equal to carbaryl at 2.0 pounds.

At Brownsville, Tex., Shell SD-9129 at 0.8 pound and Bayer 44646 at 2 pounds per acre gave better control of a heavy infestation of bollworms and tobacco budworms than 2 pounds of toxaphene plus 1 pound of DDT per acre

and produced higher yields. At Tucson, Ariz. Geigy GS-13005 and GS-12968 were less effective than toxaphene plus DDT, Shell SD-9129 was effective. Carbaryl failed to give adequate control. At Stoneville, Miss., 1 pound acre dosages of Bayer-44646, Geigy 13005 and 12968, Stauffer B-10046 and AC-52160 and an 0.4 pound dosage of Shell SD-9129 were as effective as such standards as carbaryl at 2 pounds and toxaphene at 2 pounds plus DDT at 1.0 pound per acre.

Recommended compounds were effective against bollworm moths in cage tests at Florence, S. C. Cotton plants grown in pots in the greenhouse were treated with carbaryl at 2 and 1.5 pounds, DDT at 1.5 pound and methyl parathion at 1.0 pound per acre. The plants were covered with screen cages and moths were introduced 1 and 24 hours after treatment. All insecticides were significantly better than the check 1 and 24 hours after treatment. Carbaryl at 2 pounds was better than all other insecticides and at 1.5 pound it was better than DDT or methyl parathion. DDT was better than methyl parathion.

In laboratory tests bollworm larvae from Phoenix area were nearly three times more resistant to carbaryl than those from Tucson, Arizona. Results of topical applications, dosage-mortality tests, with 365 F_1 generation larvae from pupae collected in a field located in one of the heavily treated areas near Phoenix compared with 1140 F_1 generation larvae from Tucson showed that the Phoenix bollworms were 2.67 times more resistant to carbaryl than the larvae from Tucson.

In various tests at Florence, S. C., in 1964 granular formulations of the candidate systemic insecticide, UC-21149, were ineffective against bollworms. In one test the treated cotton had fewer squares than the untreated cotton. This was probably due to increased numbers of bollworm larvae on the treated cotton because of depleted predator population.

Bidrin, Shell SD-9129, and American Cyanamid CL-47031 showed promise as stem treatments for bollworm control at College Station, Tex. Newly hatched larvae were caged on terminals of individually treated plants growing in the field. Mortality records showed up to 80% control. Shell SD-9129 was the most effective compound.

3. Other Insects. At Waco, Tex. in 1964 UC-21149 applied at 1 pound per acre in a granular formulation in the furrow at planting gave better fleahopper control than granular phorate applied in like manner at rates of 0.3, 0.7, and 1.2 pounds or as a seed treatment at 0.21 pound per acre. There was earlier fruit set in the UC-21149 treatment because of the superior fleahopper control and it produced significantly higher yield than all other treatments.

Side-dress applications of American Cyanamid CL-47031 and phorate granules prevented infestations of the desert spider mite in a field experiment at Waco, Tex. in 1964. A bollworm infestation developed in an experiment conducted to compare different methods of applying systemic insecticides for cotton fleahopper control. The entire experiment received 7 applications of carbaryl at 2 pounds per acre between July 10 and August 8. Infestations of the desert spider mite in the plots that received side-dress applications of CL-47031 and phorate on June 2 remained light through the season.

Infestations did not build up to injurious levels until August in plots in which CL-47031 was applied as a stem treatment on June 9. Plots that were treated with toxaphene plus DDT on June 11 and the original check required treatment for spider mite control on July 24.

Systemic insecticide UC-21149 was effective against plant bugs in various tests in 1965. At Stoneville, Miss., in greenhouse and field cage tests UC-21149 was effective against the tarnished plant bug Lygus lineolaris for a longer period after planting than NIA-10242, GC-9506, phorate or Di-Syston. At Tucson, Ariz. in greenhouse tests UC-21149 at 2 pounds per acre in a granular formulation gave 93% kill of Lygus hesperus. NIA-1042 and phorate were ineffective at the same dosage.

New systemic insecticides show promise for thrips control of seedling cotton in field tests in 1965. At Stoneville, Miss. UC-21149 applied as a granular formulation at planting or sprayed on the seed gave outstanding control although control with NIA-10242 and GC-5306 was good. At Waco, Tex. NIA-10242 and phorate each at 1.1 pound and UC-21149 at 2, 1.3 and 0.6 pound per acre applied as granules in the furrow at planting gave good thrips control for 9 weeks. There was no difference among systemic insecticides but all of them were significantly better than the check. At Tallulah, La. thrips control with UC-21149 applied in a granular formulation in the furrow at 1 pound per acre was equal to that obtained with the same rate and application of phorate and Di-Syston.

Stem and side-dress treatments with systemic insecticides were effective in greenhouse tests against lygus bugs at College Station, Texas. Union Carbide UC-21149 was the best compound tested. It was effective for 20 to 30 days after treatment against nymphs and adults.

In field experiments at Waco, Tex. in 1965, SD-9129 at 0.25 and 0.5 pound per acre applied as a stem treatment and UC-21149 as a granule side-dress application at 2.18 pound per acre gave fleahopper control equal to that obtained with 1.0 pound of toxaphene plus 0.5 pound of DDT applied as a conventional spray.

UC-21149 at 2.0 and 1.3 pounds per acre applied as granular formulations in the seed furrow at planting gave good fleahopper control for 10 weeks after planting in field experiments at Waco, Tex. in 1965. On June 29, approximately 10 weeks after planting, the infestation per 100 terminals in the various in-furrow treatments was as follows: UC-21149 at 2.0, 1.3, and 0.6 pounds per acre, 2.8, 5.8, and 28.3 fleahoppers respectively; 1.1 pound of NIA-10242, 36.5; 1.1 pound of phorate, 46.8; and untreated check, 42.5. The longer effectiveness of the UC-21149 this year compared with that of 1964 is probably due in part to the small size of the plants which were stunted by excess moisture during May.

In various tests at Florence, S. C., in 1964 granular formulations of the candidate systemic insecticide, UC-21149, were effective against thrips, the cotton aphid and spider mites but they were ineffective against cabbage loopers.

Laboratory and limited field data at College Station, Tex. indicated that Azodrin and UC-21149 applied to cotton stems are effective against lygus bugs, fleahoppers, spider mites, and cotton aphids. The insecticides applied with a tractor mounted rotary brush applicator gave better insect control than when they were applied with a lateral spray applicator.

Several new insecticides were effective against tarnished plant bugs in field tests at Stoneville, Miss. in 1965. GC-6506, MC-A-600, Bayer 44646, GC-9160, GC-1300 S and SD-9129 applied as sprays in field tests all gave good control of this pest.

Residual effectiveness of trichlorfon against the cotton fleahopper was poor in field tests at Waco, Tex. in 1965. Three days after treatment, SD-9129 and Bidrin each at 0.1 pound per acre gave fleahopper control equal to that obtained with 1.5 pound of toxaphene plus 0.75 pound of DDT per acre. Control with trichlorfon at 0.5 pound was less effective and at 0.25 pound was poor.

Several candidate insecticides were promising against thrips applied as sprays in field tests. At Stoneville, Miss. GC-6506, SD-9129, GC-9160 and GS-13005 gave control comparable with that of the standard. At Waco, Bidrin SD-9129, Geigy 13005 each at 0.1 pound and Bayer 44646, MC-A-600 and carbaryl each at 0.5 pound per acre gave good initial thrips control with no difference among treatments. One week after treatment Bidrin and SD-9129 were more effective than all other insecticides except carbaryl.

Ultra low volume applications of malathion and methyl trithion were effective against thrips. Technical malathion applied at 1 pint (1.25 pound) per acre to 30 acres of cotton gave good control of thrips at Tempe, Ariz. It was more effective than dieldrin at 0.5 pound per acre in a total volume of 3 gallons of spray. At Waco, Tex. there was no difference in thrips control with malathion at 1/4 and 1/2 pint (5 and 10 ounces) and methyl trithion at

0.25 pound per acre and Guthion applied as a conventional spray at 0.25 pound per acre. All of the treatments reduced the thrips population significantly below that of the check. Ultra low volume malathion applied at 1/4 and 1/2 pint (5 and 10 ounces) per acre gave good control of a heavy thrips infestation at Tallulah, La.

Bayer 52553, Stauffer B-10228 and Upjohn U-20493 were highly effective at 0.25 pound per acre or less against adult lygus bugs in laboratory tests at Tucson, Ariz. In tests against fourth-instar salt-marsh caterpillar larvae General Chemicals GC-6506 and Virginia-Carolina VC 9-104 at 1 pound per acre gave mortalities of 83 and 87 percent, respectively, in 72 hours.

The toxicity of insecticides to bollworm predators was determined in laboratory tests at College Station, Tex. Insects were either treated topically or exposed to a treated surface. Results showed that trichlorfon, demeton and phosphamidon were less toxic than Bidrin and methyl parathion to Hippodamia convergens, Collaps balteatus, Chrysopa spp. and Orius spp.

Toxicity of several insecticides to the parasite Campoletis perdistinctus was determined at Brownsville, Tex. Fifteen insecticides, all applied at 0.47 pound per acre, were compared for toxicity to C. perdistinctus in laboratory tests. DDT and TDE did not cause mortality at this rate, but methyl trithion, carbaryl, and toxaphene-DDT gave mortalities of 29%, 60%, and 80%, respectively. All other treatments gave 100% mortality.

In the laboratory at State College, Miss. the boll weevil ectoparasite, Bracon mellitor Say, developed resistance to insecticides. In topical applications to 5 or more generations the parasite developed four fold resistance to DDT, Sevin, and methyl parathion and 8 fold resistance to toxaphene-DDT. No resistance developed when toxaphene was applied alone. Although resistance levels were relatively low, the studies to indicate that mechanisms for developing resistance to insecticides do occur in the species.

4. Pink Bollworm. The DDT-resistant laboratory pink bollworm culture which originated at Presidio has been reared through 20 generations at Brownsville. Adults were treated topically with DDT in acetone at 1 µl of solution per moth at dosages of 7.5 and 10.0 µg of DDT per moth. Mortality and therefore susceptibility increased considerably in the 20th generation compared with that of the 17th through 19th generations. Approximately 50 moths will start the 21st generation.

C. Biological Control

1. Boll Weevil. Boll weevils were infected with Mattesia grandis spores in field cage tests with a granular formulation containing the spores, agar, sugar and feeding stimulant at State College, Miss. Tests in 30"

x 30" x 30" cages failed to show differences in incidence of infection when formulations were prepared without sugar, feeding stimulant or both. A test in 6' x 7' x 24' cages designed to observe population reduction over 2 generations resulted in sufficient infection to produce some reduction, but it is not known if the degree of reduction was significant. Mattesia grandis and a microsporidian were produced in sufficient quantities for field tests by infecting boll weevil larvae at State College, Miss. A spore suspension was sprayed on larvae in diet plates. The yield of spores per insect was 2×10^6 (M. grandis) and 1.3×10^8 (microsporidian). With these methods the microsporidian could probably be mass produced at an economically feasible cost. More economical methods would have to be developed to produce M. grandis.

In October and November 1964 a high number of adult dead weevils found in bolls in a cotton field near State College, Miss. were killed by naturally occurring diseases. External fungal growth was evident on the weevils. Two types of fungi were produced after separation and incubation and over 60 bacterial cultures from internal content of the weevils. The majority of the bacterial isolates belonged to the Cloaca A or Serratia groups of Enterobacteriaceae. Representative cultures injected into adults did not produce mortality compared with 100% mortality with injected S. marceseus.

A nematode, Hexamermis sp., 2 3/8 inches long was recovered from a weevil at Tallulah, La. The nematode was dissected from an overwintered boll weevil collected on a greenhouse grown plant used as a trap near a hibernation site.

The parasite, Bracon mellitor, was reared successfully on boll weevil larvae developing on artificial medium in petri dishes in the laboratory at State College, Miss. Almost 100% of the weevil larvae were parasitized when a multi-perforated cotton leaf disk was placed over open larval cells. Molds proved to be a real problem and prevented most adult parasites from emerging.

In studies at State College, Miss. Bracon mellitor females laid an average of 7.5 eggs per day in the adult age span of 6 through 26 days. This average was quite consistent for the 5 females observed. The highest rate occurred on the 12th day when the females laid an average of 10.8 eggs.

Eight hundred and thirty-three Bracon mellitor females released per acre per week in a cotton plot at State College, Miss. from July 30 through August 27 maintained a consistently high population of this parasite until frost in mid-November. Beginning September 17, or 3 weeks after termination of Bracon releases, to mid-November, weekly dissections of shed fruit showed that an average of 48% of the weevil larvae were parasitized.

Personnel of the Boll Weevil Research Laboratory of State College, Miss. found that a little known braconid parasitized a high percentage of boll weevil larvae in Guatemala. In Alta Verapaz Urosigalphus schwarzi Cwfd. parasitized 38% and 60% of larvae infesting dooryard Gossypium hirsutum and G. barbadense, respectively.

2. Bollworms. The nuclear polyhedrosis virus was tested against bollworm-tobacco budworm complex in field experiments on cotton in 1964. In one experiment at Brownsville, Tex. a dosage equivalent to 1,000 diseased larvae per acre was more effective than 100 larvae per acre. A dosage of ten larvae per acre was no better than the check. In another experiment a dosage of 100 diseased larvae per acre was as effective as 2 pounds of toxaphene plus 1 pound of DDT per acre. The population consisted of a high percentage of tobacco budworms and Shell SD-9129 at 0.8 pound and Bayer 44646 at 2 pounds were more effective than the virus or toxaphene plus DDT. At Waco, Tex. a dosage of 100 diseased larvae per acre gave control of a light bollworm infestation equal to that obtained with carbaryl at 2 pounds per acre. In 2 experiments at Stoneville, Miss. a dosage of 100 diseased larvae per acre reduced bollworm injury below that of the check. At Tallulah, La. a dosage of 100 diseased larvae per acre gave bollworm control equal to that of 1 pound of DDT per acre. A dosage of 10 diseased larvae per acre was ineffective.

In laboratory tests at Brownsville, Tex. the Heliothis virus was compatible with the following insecticides, combination of insecticides, and insecticide adjuvants: endrin; DDT; toxaphene; carbaryl; toxaphene-DDT; xylene; paired emulsifiers, Triton X-152 and X-172; spreader-sticker, Triton B-1956; wetting agent, Triton X-100; and a buffering material, Buffer-X. Mortality of larvae fed virus-methyl parathion mixture was reduced from 61.3 for the virus alone to 42.1 percent. Mortality of larvae fed a virus-CO_2-water mixture was reduced from 39.6 for the virus alone to 25.7 percent.

Four species of Heliothis were susceptible to the Heliothis nuclear polyhedrosis virus produced at Brownsville, Tex. The Heliothis species infected with this source of virus were: H. zea (Boddie), H. virescens (F.), H. armigera (Hubner), and H. phloxiphaga (Gandr.).

Pink bollworm virus was transmitted to other Lepidoptera in the laboratory at Brownsville, Tex. Bollworm, tobacco budworm, and cabbage looper larvae became infected when fed on their standard rearing diets contaminated with the cytoplasmic polyhedrosis virus found in the pink bollworm laboratory culture. The virus could not be detected in the southern armyworm under similar diet contamination. It had not been found previously in laboratory cultures of the bollworm, tobacco budworm, and cabbage looper.

Parasitism of Heliothis eggs by Trichogramma in the fall was high on crops not treated with insecticides in the lower Rio Grande Valley of Texas. An average of 72% of Heliothis zea and H. virescens eggs collected during September-November on tomato plants, 52% on corn, and 17% each on pepper and on an experimental planting of cotton were parasitized. The corn and tomato fields were not treated with insecticides. The parasite showed no preference between the two hosts. H. virescens was not found on pepper and corn.

Parasites were reared on Heliothis larvae on artificial medium. A rearing method was developed and life-history studies made of Campoletis sp., the most abundant larval parasite of H. zea and H. virescens collected locally from wild and cultivated host plants near Brownsville, Tex. Young hosts were crowded on rearing medium in glass jars until after exposure to the female parasite. After a 1-day exposure they were removed and placed on fresh medium in individual containers. Hosts 3-5 days old were preferred for oviposition. Parasitism at this stage averaged 90%. Females parasitized from 9 to 49 host larvae with an average of 27 per female.

Parasitism of Heliothis spp. on cotton was greatest when insecticide usage was low. The proportion of eggs parasitized by Trichogramma was 4.3% in May, before the general use of insecticides, and 17.5% in late August following a decrease in insecticide applications after the middle of July. No egg parasitism was found in June and July when insecticide usage was widespread. Larva parasitism was 15.6%, 0.7%, 2.0%, and 3.3% for May, June, July, and August, respectively. The low parasitism during midseason undoubtedly was due to extensive insecticide applications at that time.

Two and one-half percent of 356 bollworm eggs collected from cotton fields near Tucson, Ariz. in 1964, were parasitized by Encarsia lutea (Masi).

The eulophid parasite Encarsia lutea (Masi) reproduces males parthenogenetically. A total of 105 bollworm and cabbage looper eggs from laboratory reared moths at Tucson, Ariz. were exposed to 203 virgin females that parasitized 40 eggs. Thirty-four male parasites were recovered from these parasitized eggs.

A high percentage of bollworm larvae collected from cotton in Mississippi in October, 1964 were parasitized. The percentage of Heliothis zea was 22.2 and of H. virescens, 20.

Preliminary results of studies conducted under contract by the Entomology Department, Mississippi Agricultural Experiment Station, indicate that a number of predacious insects are present in the cotton field during the growing season. These predators cannot withstand repeated, close interval applications of insecticides at late-season dosages and are reduced by repeated early-season applications. The studies also indicate that early-season insecticides can be applied in such manner so as to obtain economical

control of early season insects and preserve predators to aid in controlling later bollworm infestations. In general boll weevil infestations appeared to be the determining factor in starting regularly scheduled applications for cotton insect control.

3. Pink Bollworm. A virus, confirmed by symptomology and electron microscopy as a cytoplasmic polyhedrosis virus, has been isolated from larvae and adult pink bollworms from a laboratory culture. This is the first record of a virus disease of pink bollworms.

Mattesia grandis collected from boll weevils infected other insects at Brownsville, Tex. In laboratory tests, the pink bollworm, cabbage looper, bollworm, and tobacco budworm became infected with M. grandis when the artificial media on which the insects were reared were surface-contaminated with spores. Observations indicated that pink bollworm larvae produced the greatest yield of spores and, therefore, might be used advantageously for laboratory production of the pathogen.

A virus reduced yield in pink bollworm mass rearing program at Brownsville, Tex. A cytoplasmic polyhedrosis virus caused considerable larval mortality, loss of adults which failed to enter traps, and sometimes a reduced fecundity of those that entered traps. In tests on virulence of the virus, the surface of the larval diet was contaminated with polyhedral inclusion bodies (PIB) at rates of 73.6, 735.6, and 7356.3 PIB/mm^2. These respective dosages resulted in larval mortalities of 12.3, 29.3, and 65.9 percent. The virus also reduced the weight and increased the development period of survivors.

4. Other Insects. Four percent of 492 cabbage looper eggs collected from cotton fields near Tucson, Ariz. in 1964 were parasitized by Encarsia lutea (Masi).

D. Insect Sterility, Attractants, and Other New Approaches to Control.

1. Boll Weevil. A large scale field experiment in Baldwin County, Alabama, combining diapause control with spring insecticide treatments or release of sterile males reduced boll weevil populations to very low levels. Eight applications of methyl parathion at 0.5 pound per acre at weekly intervals in the fall of 1963 were effective in reducing the boll weevil population on 135 acres on 20 farms. Woods trash examinations and inspection of trap plants placed in and near the treated fields were negative in the spring of 1964. The first boll weevil found in a treated field was during the week of June 15. Seven applications of 0.5 pound of Guthion plus 1.0 pound of DDT per acre were made to 10 fields during the period of June 15 to July 20. On August 26, 5 weeks after termination of insecticide treatments, the average infestation was 1.4% punctured squares with a range from zero to 5.5%. Sterile males were released at weekly intervals in 9 fields in numbers considered adequate to prevent normal reproduction. In 3 of these fields insecticides were programmed with sterile

releases. Dissection and hatch records showed that 64% of the eggs laid in these 3 fields failed to hatch. In the remaining 6 fields only non-viable eggs were found up to August 6. It was not until August 24 that viable eggs, or larvae, finally were found in all 6 remaining fields. These records, and data from shed fruit, show that both sterile male releases and chemical control drastically reduced the number of weevils in these tests.

Boll weevil populations were reduced in cotton treated with apholate spray at 1, 2, and 4 pounds per acre in one half-acre cages at State College, Miss. The treatments significantly reduced egg hatch, numbers of larvae in infested squares and consequently the number of emerging adults. Differences in treated and untreated cotton were evident several days after treatment. Phytotoxicity in the form of a significant reduction in square production was observed in the apholate treated cotton.

In tests at State College, Miss. dipping of male boll weevils in a 1% mixture of tretamine and apholate resulted in low mortality but insufficient sterility, whereas dipping in a 2% solution resulted in excellent sterility but excessive mortality. Two triphenyl tin compounds proved ineffective as chemosterilants for the boll weevil. Dipping of females, males, and both sexes in hempa resulted in little or no sterility with females alone and a slightly higher degree of sterility when both sexes were dipped than when only males were dipped. Several phosphoramides screened as chemosterilants were ineffective.

In studies at State College, Miss., of 38 candidate chemosterilants fed to boll weevils for 48 hours in sugar water only ENT 50987 showed promise. At 0.5 percent an average of 95% of the eggs laid were infertile. At a 5% concentration eggs laid on the 7th and 14th day failed to hatch. Thirty-six percent of the weevils died by the 14th post-treatment day.

In laboratory tests at State College, Miss. weevils exposed to dry film residues of apholate, tepa, and ENT 50987 laid sterile eggs. Mortality was very high with ENT 50987 but considerably less with apholate and tepa. It required 4 hours of exposure to tepa residue to achieve complete sterility and 24 hours for apholate and ENT 50987.

ENT 50987 and 50664 showed promise as boll weevil chemosterilants in laboratory tests at State College, Miss. In preliminary dip tests with mixed sexes, 14 day post-dip mortalities with ENT 50987 ranged from 30 to 74%. All eggs laid 7 and 14 days after treatment failed to hatch. Some hatch occurred in eggs laid by weevils dip treated with ENT 50664.

In studies at State College, Miss. the response of boll weevils to a narrow band of light peaking at 510 nanometers increased with intensity up to approximately 40 microwatts/cm^2. The response appeared to level off at higher intensities. A 10-minute exposure period with 11-20 weevils per test appeared to give maximum response.

A rapid laboratory technique involving simple apparatus for bioassaying plant attractants for the boll weevil was developed at State College, Miss. In 51 replicated tests with this technique a water extract of cotton squares attracted more weevils than the checks. The ratios varied from 3:1 to 40:1 with an average of 8.5:1. The number of boll weevils responding ranged from 38% to 94%, with an average of 68.3%.

Plant attractant preference of the boll weevil to 11 species of Malvaceae was determined at State College, Miss. The order of preference follows: (1) C. digitata; (2) C. sulphurea (Texas); (3) G. hirsutum DPSL; (4) C. argentina; (5) T. populnea; (6) C. heterophylla; (7) C. involucrata; (8) C. sulphurea (Argentina); (9) A. esculentus (Okra); (10) H. clypeus and (11) H. syriacus.

Gas chromatography studies of the boll weevil plant attractant at State College, Miss. showed that at least 57 compounds are present in the square volatile fraction. These compounds include saturated and unsaturated aldehydes and ketones, saturated and unsaturated hydrocarbons (terpenes and sesquiterpenes), alcohols, acids and amines. Little evidence has been obtained for phenols and esters.

Stem treatment with American Cyanamid CL-47031 plus foliar spray of feeding stimulant showed promise against boll weevils in tests at College Station, Texas. In a large field cage test with American Cyanamid CL-47031 applied as a stem treatment at 0.7 pound per acre or granular side-dressing at 10 pounds per acre, early season boll weevil control was obtained. The side-dressing was more effective than the stem treatment, but the 10 pounds per acre dosage caused some phytotoxicity. A side-dressing at 2 pounds per acre showed little promise. In a late season test with large, fruiting cotton the CL-47031 stem treatment alone was not effective; however, when the stem treatment was combined with foliar feeding stimulant sprays, considerable boll weevil mortality was obtained.

In a replicated cage study at Florence, S. C. the following treatments were compared to test weevil attractancy: cotton plants; cocklebur plants; forms covered with green painted plastic; and forms covered with red painted plastic. Field cages 6 x 6 x 36 ft. covered the treatments. The test area was bounded by woods on 3 sides and the nearest cotton was 300 yards to the west. The cages were inspected from May through September. Numbers of weevils collected were as follows: cotton, 182; cocklebur, 8; green forms, 3; and red forms 3. It appears that weevils located the cotton through odor since the cocklebur treatment was similar in mass and color and the green forms reflected similar light.

In studies at State College, Miss. significant differences were found in boll weevil feeding on extracts from seven species of Malvaceae. Weevil feeding on plugs containing extract from Gossypium hirsutum, (DPSL), Thespesia populnea and Cienfuegosia sulphurea was significantly higher

than on those containing Hibiscus syriacus, Callirrhoe involucrata, Callirrhoe digitata and Hibiscus sp.

Research on the isolation of boll weevil feeding stimulants found in the flower buds and flowers of cotton plants is conducted under contract by Southern Research Institute, Birmingham, Alabama. Semi-Annual Report No. 2 describes investigations of feeding-stimulant activity extractable by water and other polar solvents, such as methanol, and studies on the isolation of active components extractable by chloroform and non-polar solvents, such as hexane and ether. Boll weevil feeding behavior in the "rolled-plug" assay was inconsistent. Feeding on crude water and chloroform extracts was normal in January but became erratic early in February and frequently dropped to low levels. Erratic feeding in the assay continued through March and early April. During the latter part of April and in May feeding activity on crude water extracts reached high levels.

2. Pink Bollworm. At Brownsville, Tex. metepa-sterilized males released in a large cage test simulating natural conditions reduced pink bollworm populations 80-90% below that of an untreated check. The estimated release ratio for the season was 7:1 (sterile male: existing natural moths) and varied from 1:1 to 186:1. However, populations increased despite the release of sterile males. The study is being continued to take advantage of mortality from cultural practices and other factors affecting over-wintering populations.

Use of sex lure traps failed to reduce pink bollworm field infestation at Torreon, Mexico. Although over 12,000 males were collected over a $2\frac{1}{2}$ month period in 49 traps, first-generation infestation was the same as that in an adjacent part of the field without traps. Lack of isolation and other factors may have resulted in the ineffectiveness of the trapping. However, considerable information on use of the sex lure traps was obtained during the season.

The duration of activity of the pink bollworm sex lure was not influenced by different solvents in tests conducted in the fall of 1964 at Brownsville, Tex. Traps baited once with 100 female equivalents of the lure dissolved in acetone, benzene, hexane, methylene chloride, or ethyl ether captured as many males as traps baited twice weekly with similar amounts of methylene chloride extract for a period of 3 weeks. After this time their catches dropped below those of the trap baited twice a week. No differences between solvents were noted.

In studies at Brownsville, Tex. female pink bollworm moths sterilized with metepa were competitive with normal females. Dosage of technical metepa topically applied required to sterilize females was 60 µg/moth. At a dosage of 30 ug/female, 10% of the eggs deposited hatched. Treated females were competetive with normal females at dosages from 30 to 60 µg when caged with normal pairs so that the ratio of treated to normal females was 4:1.

E. Evaluation of Equipment for Insect Control and Detection.

1. Boll Weevil. In an isolated field test in Florida, a flail type machine for destroying fallen weevil-infested squares held the infestation over an 8-week period to a maximum of 10.2%. A nearby untreated check had an infestation of 46% punctured squares 10 days earlier when insecticide treatments were begun. The treated area received 5 treatments with the flail machine beginning before emergence of F_1 weevils.

2. Bollworms. High frequency sound affected moth activity in studies at Florence, S. C. Sound in the range of 21 to 50 kc disrupts normal flight patterns of a number of tympanate moths including Heliothis zea. In preliminary studies the high frequency capacitor transducer developed for bollworm studies was effective in reducing the attractiveness of one of a pair of black light traps to tympanate moths.

At Waco, Tex. fewer bollworm moths were collected in a black light trap in 1964 than in previous years. Only 7,215 moths were collected in a black light trap during 1964 which is the lowest number for any year of the 9 year period, 1956-1964. In 1963, 30,056 moths were collected.

In recent studies at Florence, S. C. with a high frequency microphone not previously available, it was determined that a switching artifact of 30-50 kc was present in the 200-4000 CPS stimuli used in 1963 H. zea acoustic studies. The moths were actually responding to the high frequency switching artifact rather than the low frequency stimulus. The switching artifact has now been eliminated through use of electronic switch to shape the pulse. The low frequency response limits have been redefined at 6-8 kc.

A high frequency transducer was calibrated with a B & K condenser microphone at Florence, S. C. The high frequency transducer used in the Heliothis zea studies was found to have a maximum output in the 60 KCPS range as determined with a recently acquired Bruel and Kjaer 0.25" condenser microphone.

3. Pink Bollworm. Pink bollworm sex-lure trap design and killing agents were investigated at Brownsville, Tex. Traps made of various cylinders about 10 inches in diameter with invaginated funnels or baffle plates appear superior to modified gypsy moth traps. A Steiner trap equipped with invaginated funnels also shows promise. Calcium cyanide was far superior to Vapona resin pellets as a killing agent placed in the traps in cage and field tests.

Pink bollworm moths collected in a light trap at Waco, Texas increased each year from 1953 to 1958 with the highest collections being made in 1958. Collections decreased sharply in 1959 with little difference in

numbers collected during the years 1959-1962. Fewer moths were collected in 1963 that in any year since 1954. In 1964 more moths were collected than in any year except 1958.

F. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. Average emergence weights of boll weevils from field-collected squares of five cotton lines were nearly equal to weights of weevils reared from square powder diets from the same varieties. Emergence weights of weevils reared on Rex Smooth Leaf and Acala 4-42-77 were lower than for those reared on glandless Rex Smooth Leaf and glandless Acala 4-42-77 for both square-emerged and diet-emerged weevils. Pima S-2 produced the smallest weevils of any variety in the study. Lyophilized square powder diets with gossypol and gossypol gland contents added produced smaller boll weevils which took longer to emerge than a square powder diet containing no additional gossypol or gland contents. No weevils emerged on the diet containing 2% gossypol and only 1 weevil emerged on the diet containing 1% gossypol and only 1 weevil emerged on the diet containing 1% gossypol out of approximately 70 incubated vials. Pure gossypol was more toxic than gland contents.

In replicated oviposition tests with laboratory-reared weevils at State College, Miss., 15 cotton lines reduced boll weevil oviposition more than 15%. One line reduced oviposition 38%. Preliminary data indicate genetic control of this factor in the cottons under study. Twenty-four cotton lines produced boll weevils 18% smaller than those produced on DPSL. A standard antibiosis technique was used in these tests. Weevils required 2-3 days longer to develop from egg to adult on a few lines.

Tests at State College, Miss. indicated that glandless cotton is not more susceptible to boll weevils than glanded lines. Boll weevil feeding, oviposition and antibiosis experiments with 13 glandless "isogenic" cotton lines and their glanded parents show that the glandless genes $gl_2gl_2gl_3gl_3$, will not create a significantly greater degree of susceptibility to the boll weevil over glanded varieties. However care must be exercised in the initial selection of the genetic background in which the genes are placed.

2. Bollworms. Glabrous-nectariless cotton (1514) showed resistance to bollworm in field tests. Fewer bollworm eggs were laid on the cotton variety 1514 than on commercial varieties in each of four test fields at Brownsville, Tex., with seasonal average reductions ranging from 43 to 58%. Although all the fields were treated with insecticides for bollworm control, there were differences in square and boll damage between 1514 and check varieties. The seasonal average percent of damaged bolls, in respective fields of 1514 and the check were: 0.6 and 2.3; 2.5 and 4.2; 0.8 and 1.2; 3 and 5. Heavy fleahopper infestations developed in only one field, with fewer fleahoppers on 1514 than on the check in each of four weekly counts

totalling 138 compared with 738. Yields of 1514 compared favorably with check yields. At Waco, Tex., the bollworm infestation was light and there was no difference in bollworm damage among 1514, Lankart and Delta Pine Smooth Leaf. At Stoneville, Miss., 1514 had fewer squares and bolls damaged by bollworms than Delta Pine Smooth Leaf.

At Tucson bollworm larvae reared on glandless cotton foliage were heavier and developed faster than those reared on glanded cotton foliage. The average weight of thirty 10-day old larvae reared on a food medium made of Glandless (AXTE-25) cotton leaves supplemented with ascorbic acid and Brewers' yeast was 337 milligrams of 2.6 times greater than similar larvae reared on leaves from glanded cotton. The average development time from egg hatch to moth was 30.1 days for glandless leaf fed larvae and 34.8 days for glanded leaf fed larvae.

Heliothis larvae developed better on glandless than on glanded cotton in laboratory tests. Bollworm and tobacco budworm larvae were reared on lyophilized squares which had been reconstituted with water, agar, and mold inhibitors. Those reared on glandless square material were significantly larger than those on the corresponding glanded strains. In some instances the growth rate on the glandless strains was more than two times greater than on the glanded strains. Larvae of both species also grew larger on glandless cotyledons than on glanded ones.

In studies at Brownsville, Tex. experimental cottons inhibited growth of tobacco budworms. Lyophilized squares of lines from eight families were bioassayed for degree of inhibition of larval growth of the tobacco budworm. Results were similar to those previously reported for the bollworm. Larval growth was related to gossypol content of the seed and squares. Generally lines with the higher gossypol content produced smaller larvae. However, a few lines with relatively low gossypol content produced larvae that were smaller than those from a DPL-15 standard. Of 87 lines tested, 38 produced larvae smaller than those from the standard. The larvae on all lines were larger than those from Pima S-2 which had a higher gossypol content than the experimental lines.

Bollworm survival, growth rate, and pupation was affected by gossypol in studies at Tucson, Ariz. In laboratory tests when 0.3% gossypol was added to lima bean food medium, larval mortality was 50% greater than in the checks. The average weight of 10-day old larvae on the diet containing gossypol was only 3.6 mg compared with 590 mg for those on the checkouts. Gossypol levels as low as 0.075% noticeably reduced larval weights. Ninety two and five-tenth percent of the larvae pupated with 15 days on the check diets while 75% pupated in 15.8 days on the diet containing 0.05% gossypol level and 45% pupated in 41.6 days at the 0.3% level.

In studies at Brownsville, Tex. growth rate of Heliothis larvae was related to gossypol content of cotton plant. It has been previously reported growth rates of H. zea and H. virescens larvae were greater on diets of glandless than on glanded lyophilized cotton squares and cotyledons of six isogenic strains.

Chemical analysis showed that squares and cotyledons of the glanded strains had several times the gossypol content of the glandless strains. Larval growth appeared to be directly related to the gossypol content. Previous work has also shown that glandless plants were highly attractive to several insects that rarely attack commercial varieties.

In studies at State College, Miss. reciprocal grafts of Rex S. L. glanded and glandless cotton showed a reduction in free gossypol in squares from glanded scions compared with squares from glanded stocks and non-grafted glanded plants. The data supports the hypothesis that gossypol or a precursor is produced predominantly in the roots of glanded plants, that glandless plants have a reduced ability to produce and to store gossypol, and that gossypol is translocated in some form.

Cienfuegosia exhibits genetic characters needed in cotton for resistance to insects. The genus Cienfuegosia is known to have numerous glands in vegetative parts but the seeds are gland-free. Chemical analyses at Brownsville, Tex. showed that the gossypol content of vegetative parts was high but that of the seeds was extremely low. If this condition existed in cotton the glandless seeds would provide gossypol free meal which would be a source of protein for human and non-ruminant animal consumption.

3. Other Insects. Grape colaspis (Maecolaspis flavida) and striped blister beetle (Epicauta vittata) readily attacked glandless lines of cotton. Approximately 28 different "isogenic" glandless lines were damaged by grape colaspis while their glanded parents and other glanded lines were not damaged. Striped blister beetles moved into large field plots of Rex Smooth Leaf and Acala 4-42-77 glanded and glandless lines and Delta Pine Smooth Leaf, damaging only the glandless lines.

Laboratory feeding tests at Tucson, Ariz. indicated that high gossypol cotton varieties are more resistant to beet armyworm larvae than low gossypol varieties. The average weight of 10-day old larvae reared on leaves of low gossypol strains (.042% or less gossypol), AXTE Glandless, A-44-10-1 and Dwarf AXTE-Lankart F_2 were 8.6, 4.64, and 4.17 grams, respectively. This compared with an average weight of 1.38, 1.32, and 1.27 grams for larvae reared on leaves of high gossypol strains (0.1 + gossypol), Red dwarf, Pima 32, and 63-11 #1, respectively.

In laboratory studies at Tucson, Ariz. salt-marsh caterpillar larval development was inhibited with 0.1 percent gossypol added to diet. Average weights of 10-day old salt-marsh caterpillar larvae fed lima bean food media with 0.1 gossypol acetate added was only 1.1 milligrams compared with 82.4 milligrams for those reared on the same diet without gossypol. Mortality when larvae were 10 and 14 days old was 33 and 60 percent, respectively, compared with none in the check.

A low concentration of gossypol was lethal to salt-marsh caterpillar larvae. In laboratory feeding tests at Tucson, Ariz. 0.1% or more gossypol added to lima bean food medium resulted in 100 percent mortality within 20 days. At 0.025% gossypol the average weight of surviving 10-day old larvae was only 28.5 mgs compared with 67.5 for the check diets. The number of required days to pupation was more than doubled at the 0.05% gossypol level and 10 days longer than for those in the check at the 0.025% level.

In studies at Tucson, Ariz. glandless strains of Acala cotton were much more susceptible to white flies than their glanded counterparts. Leaf collections on June 9 showed 7 and 25 times more eggs and 4 and 3 times more adults on glandless AXTE and Acala 4-44-77 strains respectively, than on their glanded counterparts. Differences also were similar in collections made on June 16.

In studies at Brownsville, Tex. experimental cottons were resistant to cotton fleahopper and cotton aphid. Of 16 strains used in a field experiment, 4 showed resistance to cotton fleahopper. Glabrousness appeared to contribute to this resistance. Strain 1514, which is glabrous and nectariless, was outstanding in this and in another field experiment and in a cage experiment. It does not appear likely that absence of nectaries is associated with resistance to fleahopper. No obvious differences were noted between glanded and glandless strains. In the cage experiment, cotton aphid populations were lower on seven glabrous strains than on M-8 which is hirsute.

G. Insecticide Residue Determinations.

In cooperation with the Plant Pest Control Division a large number of soil samples were analyzed at Tifton, Ga. and Kerrville, Tex. for methyl parathion or for arsenic for the Mississippi River Basin pesticide monitoring program. A large proportion of the samples analyzed for methyl parathion showed the presence of this insecticide but in amounts less than 1 ppm. The arsenic residues ranged generally from about 0.5 to 19.0 ppm with the greater number of samples falling near the 10 ppm level.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Agee, H. R. 1964. Characters for determination of sex of the boll weevil. J. Econ. Entomol. 57:500-1.

Bottger, G. T. 1965. Stub cotton provides haven for western boll weevil. Progressive Agri. in Ariz. XVII:12-13.

Bull, D. L. 1965. Metabolism of Di-Syston by insects, isolated cotton leaves and rats. J. Econ. Entomol. 58:249-54.

Bull, D. L. and D. A. Lindquist. 1964. Metabolism of 3-hydroxy-N,N-dimethyl-crotonomide dimethyl phosphate by cotton plants, insects and rats. J. Agri. Food Chem. 12:310-17.

Burks, Marcus L. and Norman W. Earle. 1965. Boll weevil diets--Amino acid composition of upland cotton squares and Arizona wild cotton bolls. J. Agri. Food Chem. 13:40-42.

Davich, T. B., D. A. Lindquist and Joseph Hacskaylo. 1965. Implanting boll weevil eggs in cotton squares for systemic insecticide and host-plant resistance studies. J. Econ. Entomol. 58:366-68.

Everett, T. R. 1964. An inherited behavioral variant in the boll weevil. J. Econ. Entomol. 57:760-61.

Everett, T. R. and N. W. Earle. 1964. Boll weevil oviposition responses in cotton squares and various other substrates. J. Econ. Entomol. 57:651-56.

Lambremont, E. N. 1965. Fatty acid biosynthesis in asceptically reared insects. J. Comp. Biochem. and Physiol. 14:419-24.

Lambremont, E. N., M. S. Blum and R. M. Schrader. 1964. Storage and fatty acid composition of triglycerides during adult diapause of the boll weevil. Ann. Entomol. Soc. Amer. 57:526-32.

Lambremont, E. N. and R. M. Schrader. 1964. Electrophoresis of an insect pyrophosphatase. Nature 204:883-4.

Lindquist, D. A., D. L. Bull and R. L. Ridgway. 1965. Systemic activity of Bidrin in the cotton plant. J. Econ. Entomol. 58:200-03.

Lindquist, D. A., Joseph Hacskaylo and T. B. Davich. 1965. Effect of light and humidity on the absorption and translocation of dimethoate in the cotton plant. J. Econ. Entomol. 58:415-18.

Mitlin, Norman and D. H. Vickers. 1964. Quanine in the excreta of the boll weevil Anthonomus grandis (Boheman). Nature 203:1403.

Mitlin, Norman, D. H. Vickers and R. T. Gast. 1964. Estimation of nitrogenous compounds in the feces of boll weevils Anthonomus grandis fed different diets. Ann. Entomol. Soc. Amer. 57:757-59.

Mitlin, Norman, Allan C. Bartlett and J. C. Keller. 1965. Elimination rate and effect on reproduction of ingested radiophosphorus in the boll weevil. J. Econ. Entomol. 58:119-21.

Moore, R. F., Jr. and H. M. Taft. 1964. Effect of DDT and toxaphene alone and in combination on succinic dehydragenase activity in homogenates of the boll weevil. J. Econ. Entomol. 57:772-73.

Moore, R. F., Jr., H. M. Taft and F. F. Whisnant. 1964. Effect on boll weevil progeny of cholesterol added to the adult diet as a powder or ether solution. J. Econ. Entomol. 57:1005.

Noble, L. W. and O. T. Robertson. 1964. Methods for determining pink bollworm population in blooms. J. Econ. Entomol. 57:501-3.

Ouye, M. T. and E. S. Vanderzant. 1964. B-vitamin requirements of the pink bollworm. J. Econ. Entomol. 57:427-30.

Parencia, C. R., Jr. and C. F. Rainwater. 1964. First findings of cotton leafworm in the United States, 1922 to 1963. J. Econ. Entomol. 57:432.

Parencia, C. R., Jr. 1964. Winter survival of the bollworm in central Texas. J. Econ. Entomol. 57:757-58.

Ridgway, R. L., D. A. Lindquist and D. L. Bull. 1965. Effect of method of application on uptake of Di-Syston by the cotton plant. J. Econ. Entomol. 58:349-52.

Richmond, C. A. and Carlo M. Ignoffo. 1964. Mass rearing pink bollworms. J. Econ. Entomol. 57:503-5.

Smith, G. L., T. C. Cleveland and J. C. Clark. 1965. Boll weevil movement from hibernation sites to fruiting cotton. J. Econ. Entomol. 58:357-58.

Smith, G. L. and A. L. Scales. 1965. The effect of air and ground surface temperature on boll weevil survival. J. Econ. Entomol. 58:174-5.

Stoner, Adair. 1965. Host plants of Spanogonicus albofasciatus in Arizona. J. Econ. Entomol. 58:322-24.

Stoner, Adair and G. T. Bottger. 1964. Spanogonicus albofasciatus and Rhinacloa forticornis on cotton in Arizona. J. Econ. Entomol. 58:314-15.

Taft, H. M. and C. E. Jernigan. 1964. Elevated screens for collecting boll weevils between hibernation sites and cotton fields. J. Econ. Entomol. 57:773-75.

Vanderzant, Erma S. 1965. Axenic rearing of the boll weevil on defined diets: Amino acid, carbohydrate and mineral requirements. J. Insect Physiol. 11:659-70.

Walker, J. K. and L. A. Bariola. 1964. Oviposition by virgin overwintered boll weevils. J. Econ. Entomol. 57:781-82.

Wene, G. P. and L. W. Sheets. 1964. Lygus bug injury to presquaring cotton, Arizona Agr. Exp. Sta. Tech. Bull. 166. 25.

Wene, G. P. and L. W. Sheets. 1965. Migration of beet armyworm larvae. J. Econ. Entomol. 58:168-69.

Insecticidal and Cultural Control

Cleveland, T. C. and G. L. Smith. 1964. Effects of postseason applications of insecticides, defoliants, and dessicants on diapausing boll weevils. J. Econ. Entomol. 57:527-29.

Cleveland, T. C. and G. L. Smith. 1965. Field tests with Di-Syston granules for thrips control on cotton. J. Econ. Entomol. 58:364-65.

Hopkins, A. R. and H. M. Taft. 1964. Field experiments for control of the boll weevil, bollworm spp. and the cotton aphid on cotton in 1960-62. J. Econ. Entomol. 57:509-11.

Lloyd, E. P., M. L. Laster and M. E. Merkl. 1964. A field study of diapause, diapause control, and population dynamics of the boll weevil. J. Econ. Entomol. 57:433-6.

Lowry, W. L. and R. S. Berger. 1965. Investigations of pink bollworm resistance to DDT in Mexico and the United States. J. Econ. Entomol. 58:590-91.

Pfrimmer, T. R. 1964. Populations of certain insects and spiders on cotton plants following insecticide applications. J. Econ. Entomol. 57:640-44.

Smith, G. L., T. C. Cleveland and J. C. Clark. 1964. Boll weevil control with emphasis on early-season and fall treatment in 1960, 1961 and 1962 at Tallulah, La. USDA ARS 33-100. 15.

Smith, G. L., T. C. Cleveland and J. C. Clark. 1965. Field tests for control of overwintered boll weevils. J. Econ. Entomol. 58:360-61.

Ridgway, R. L. 1965. Systemics for cotton. Farm Chemicals. 128:80-1.

Ridgway, R. L. 1965. Evaluation of some experimental phosphorus and carbamate compounds as systemic insecticides. USDA ARS 33-106. 6.

Biological Control

Estes, Zane E. and C. M. Ignoffo. 1965. The nucleic-acid composition of nuclear polyhedral bodies affecting Heliothis zea (Boddie). J. Invert. Pathol. 7:258-9.

Ignoffo, Carlo M. 1964. Production and virulence of nuclear-polyhedrosis virus from larvae of Trichoplusia ni (Hubner) reared on a semisynthetic diet. J. Insect Pathol. 6:318-26.

Ignoffo, C. M. 1965. Production, identification, and standardization of insect viral pathogens. Entomophaga 10:29-40.

Ignoffo, C. M., R. L. McGarr and D. F. Martin. 1964. Control of Alabama argillacea (Hubner) with Bacillus thuringiensis Berliner. J. Insect Pathol. 6:411-16.

Ignoffo, C. M. 1965. The nuclear-polyhedrosis virus of Heliothis zea (Boddie) and Heliothis virescens (Fabricius). Part I. Virus propagation and its virulence. J. Invert. Pathol. 7:209-16.

Ignoffo, C. M. 1965. The nuclear-polyhedrosis virus of Heliothis zea (Boddie) and Heliothis virescens (Fabricius). Part II. Biology and propagation of diet reared Heliothis. J. Invert. Pathol. 7:217-26.

Ignoffo, C. M., A. J. Chapman and D. F. Martin. 1965. The nuclear-polyhedrosis virus of Heliothis zea (Boddie) and Heliothis virescens (Fabricius). Part III. Effectiveness of the virus against field populations of Heliothis on cotton, corn and grain sorghum. J. Invert. Pathol. 76:227-35.

Ignoffo, C. M. 1964. Effects of temperature and water on viability and virulence of Bacillus thuringiensis var. thuringiensis Berliner spores. Entomophaga, Memoire of Series No. 2:293-98.

Ignoffo, C. M. 1964. Bioassay technique and pathogenicity of a nuclear-polyhedrosis virus of cabbage looper (Trichoplusia ni (Hubner). J. Insect Pathol. 6:237-45.

Ignoffo, C. M. and Clemente Garcia. 1965. Infection of the cabbage looper, bollworm, tobacco budworm and pink bollworm with spores of Mattesia grandis McLaughlin collected from boll weevils. J. Invert. Pathol. 7:260-62.

McLaughlin, R. E. and J. C. Keller. 1964. Antibiotic control of an Epizootic caused by Serratia marescens Bizio in the boll weevil Anthonomus grandis (Boheman). J. Insect Pathol. 6:481-5.

McLaughlin, R. E. and George Allen. 1965. Description of hemocytes and the coagulation process in the boll weevil, Anthonomus grandis (Boh.). (Curculionidae) Biol. Bull. 128:112-24.

Insect Sterility, Attractants and Other Approaches to Control

Berger, R. S., J. M. McGough, D. F. Martin, and L. R. Ball. 1964. Some properties and the field evaluation of the pink bollworm sex attractant. Ann. Entomol. Soc. Amer. 57:606-9.

Davich, T. B., J. C. Keller, E. B. Mitchell, Paul Huddleston, Ray Hill, D. A. Lindquist, Gerald McKibben and W. H. Cross. 1965. Preliminary field experiments with sterile males for eradication of the boll weevil. J. Econ. Entomol. 58:127-31.

Keller, J. C., E. B. Mitchell, G. McKibben and T. B. Davich. 1964. A sex attractant for female boll weevils from males. J. Econ. Entomol. 57:609-10.

Keller, J. C. and T. B. Davich. 1965. Response of five insect species of insects to water extracts of their host plants. J. Econ. Entomol. 58:164-5.

Keller, J. C., T. B. Davich, F. G. Maxwell, J. N. Jenkins, E. B. Mitchell and P. Huddleston. 1965. Extraction of a boll weevil attractant from the atmosphere surrounding growing cotton. J. Econ. Entomol. 58:588-9.

Lindquist, D. A., L. J. Gorzycki, M. S. Mayer, H. L. Scales and T. B. Davich. 1964. Laboratory studies on sterilization of the boll weevil with apholate. J. Econ. Entomol. 57:745-50.

Evaluation of Equipment for Insect Control and Detection

Agee, H. R. and H. M. Taft. 1964. An electronic scarecrow. Agricultural Research. 13:5.

Parker, R. E., E. C. Burt, F. E. Fulgham and M. E Merkl. 1964. Effectiveness of a USDA developed flames on boll weevil destruction inside cotton squares. USDA ARS 42-104.

Varietal Evaluation For Insect Resistance

Jenkins, J. N., F. G. Maxwell and W. L. Parrott. 1964. A technique for measuring certain aspects of antibiosis in cotton to the boll weevil. J. Econ. Entomol. 57:679-681.

Lukefahr, M. J., D. F. Martin and J. R. Meyer. 1965. Plant resistance to five lepidoptera attacking cotton. J. Econ. Entomol. 58:516-18.

Maxwell, F. G., J. N. Jenkins, H. N. Lafever, M. J. Lukefahr and G. T. Bottger. 1965. Insect situation on glandless cotton--A progress report. Proc. 17th Ann. Cotton Improvement Conf. 104 p.

AREA NO. 10. TOBACCO INSECTS

Problem. Insecticides that effectively control insects that attack tobacco, particularly budworms, hornworms, flea beetles, and aphids, have resulted in undesirable residues on cured tobacco. Such residues adhere to the leaf through commercial processing into cigarettes and some have been found in the main-stream of smoke from commercial cigarettes. Methods for controlling insect pests of tobacco that will not lead to insecticide residues in cigarettes or other manufactured tobacco products are urgently needed. Research on lures, light traps, sterilization techniques, other new approaches to control, and better utilization of predators, parasites, and diseases of tobacco insects should receive more attention. Studies to find market-acceptable tobacco varieties that resist insect attack and to develop environment-compatible insecticides that leave no undesirable residues are equally important.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic and applied research on tobacco insects to develop effective control methods for tobacco insects that will alleviate the residue problem on the harvested leaf. The research is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway and with the tobacco industry. Studies are conducted at Oxford, N. C., Florence, S. C., Quincy, Fla., and at a temporary location on St. Croix, Virgin Islands, as a satellite of Oxford. Contract research supported by the Department is in progress at the Kentucky, North Carolina, and South Carolina Agricultural Experiment Stations, and the Virginia Polytechnic Institute. A grant for studies on tobacco insects at the Clemson Agricultural Experiment Station in South Carolina has been implemented.

The Federal scientific effort devoted to research in this area totals 7.5 professional man-years. Of this number, 1.4 is devoted to basic biology, physiology, and nutrition; 1.1 to insecticidal and cultural control; 0.2 to insecticide residue determinations; 0.2 to biological control; 4.0 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; and 0.5 to program leadership.

In addition Federal support of research under contracts and grants provides 3.1 man-years in this area. Of this total 1.2 is devoted to basic biology, physiology, and nutrition and 1.9 to insect sterility, attractants and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

The tobacco-producing states have an active research program on tobacco insects and their control.

Biological research places emphasis on seasonal history and behavior of injurious insects. Much of this work consists of evaluating the effects of environmental conditions throughout the year on population dynamics and rearing the insects in the field and laboratory. For example, in the tobacco hornworm the winter survival, length of life and factors inducing and terminating diapause are being studied. The accumulation of data on abundance and its relation to climatic factors may make it possible to predict the severity of infestations of this insect.

New insecticides, particularly those believed to be heat degraded or metabolized,are being screened to determine their efficiency in controlling tobacco insects. Those materials which appear to be biologically promising are placed in advanced testing programs. Coincidentally, the fate of the residue from application through curing, ageing, and smoking is studied. New application methods, particularly those which might decrease residues, are evaluated. Attempts are being made to utilize parasites, predators, and disease organisms more effectively. Cultural controls under investigation include influences of crop rotation and fertilizer application on the kinds and numbers of insect pests that attract tobacco.

Research is in progress to isolate the female attractant from the hornworm moth and use it or other baits to lure the moths to traps.

Plant resistance studies entailing screening of varieties and foreign introduction are being conducted to locate factors conferring resistance to specific pests. Susceptibility to infestation is measured by comparing the reproduction of the pest involved on each variety, the relative tolerance of the plants to insect attack and general agronomic characteristics. Where resistance is observed, backcrosses and selections are made to convey the responsible factor to adapted varieties. Biochemical studies are performed to determine the chemical nature of the factor and its influence on the pest involved.

There are 10.6 professional man-years dedicated to research on tobacco insects by the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

Studies at Florence, S. C., during the past few years have shown that moths from overwintering tobacco hornworm pupae do not emerge as a spring brood. Instead, they begin to emerge the latter part of May and continue to emerge until around July 23.

At Quincy, Fla., light trap catches of the tobacco budworm were 24% higher than for the corn earworm April 26 through June 1, 1965.

Hornworm populations on St. Croix, U. S. Virgin Islands, based on a single

status trap, were extremely low during November 1964 through March 1965 due to a severe drouth. However, within 4 days after heavy rainfall, trap catches increased to previous levels. In March 1965, 8 additional traps were installed throughout the entire Island. Surprisingly, high catches were taken in the eastern portion of the Island which tends to be drier and with fewer host plants than other parts of the Island. However, the narrowness of the eastern portion may tend to increase the catch by channeling moths within the vicinity of the trap. Reciprocal crosses between St. Croix and North Carolina male and female hornworms were successful in producing progeny.

B. Insecticidal and Cultural Control

At Florence, S. C., a special tractor attachment for the application of insecticide granules as a row treatment for the control of wireworms resistant to chlorinated hydrocarbon insecticides was evaluated. Further cooperative studies with plant pathologists of the Crops Research Division indicated chemicals for the control of wireworms and nematodes may be combined in a single application. A new insecticide, Niagara 10242 (ENT-27164), applied to the soil in granular form for wireworm control, appears to be an efficient systemic material for the control of the tobacco flea beetle, the tobacco hornworm, and the tobacco budworm. Counts of injured plants 6 weeks after transplanting indicated good protection against all three insect species where the insecticide had been applied at rates of 4 and 6 pounds of active ingredient per acre. These application rates also gave good wireworm control.

The cabbage looper is becoming increasingly important as a pest of tobacco in South Carolina and was especially severe in 1965. By the middle of June, populations in some tobacco fields in the Florence, S. C., area were the highest on record. In one 4-acre field under observation, the loopers appeared early and continued to increase in numbers despite 8 applications of insecticides for their control.

At Quincy, Fla., the practice of applying chlorinated hydrocarbon insecticides plus parathion once or twice each week to shade tobacco has resulted in high residues on the wrapper leaf of cigars. To explore alternate methods of control that would result in lower residues, granular Di-Syston was applied to the soil as a preplant treatment at varying dosages for aphid control. The shade was then planted with insect-free plants. All levels of Di-Syston tested gave good control for about 6 weeks, whereas the check plots were destroyed by aphids in about 4 weeks. Four light traps were placed outside of the shade and one in the center. Tobacco budworm and cabbage looper damage was light.

C. Insecticide Residue Determinations

In 1963, representative samples of tobacco were obtained from 8 warehouses in North Carolina. Analysis showed the presence of DDT ranging from 3.3

to 12.0 ppm, TDE from 0 to 28.0 ppm, and endrin from less than 0.5 to 2.3 ppm. Residues found in samples of shade tobacco from growers' stocks in the Quincy, Fla., area contained 300 ppm of DDT, 0 TDE, and 13.7 endrin. Samples from 2 experimental plots of shade grown tobacco not treated with chlorinated hydrocarbon insecticides showed the presence of DDT and endrin in amounts that indicate possible translocation or contamination from the soil or contamination from some other source.

D. Biological Control

At Quincy, Fla., green lacewing eggs were placed on shade tobacco plants infested with the green peach aphid. The hatching lacewing larvae, however, were not adaptable to the highly pubescent surface of the tobacco leaves and failed to become established.

In the Oxford, N. C., light trap area, only 1 out of 24 untreated check plots showed hornworm or budworm counts justifying the use of insecticides. However, treatment was delayed several days and parasites and predators effectively eliminated the infestation.

E. Insect Sterility, Attractants, and Other New Approaches to Control

At Oxford, N. C., studies were conducted in 1963 and 1964 to determine the effectiveness of light traps for large-area control of the tobacco hornworm. Results in 1963 showed an 83% reduction in numbers of eggs and small larvae at the center of the 113-square-mile study area as compared with infestations 6 miles outside the area. In 1964 hornworm damage estimates indicated reduction of 89% at the center of the trapping area as compared with conditions 20 miles outside the area. Marked increases in stalk destruction in the trap area in the fall of 1962 and 1963 probably contributed to the resulting control. In 1963 the number of insecticide applications by individual growers for hornworm control inside the trap area was reduced about 90% and in 1964 applications for control of all tobacco insects were reduced by about 55% as compared with applications outside the area. Observations on tobacco budworm populations also indicated some control of this insect in the light-trap area. In 1964 the percent reduction in budworm-damaged plants in the center of the light-trap area, as compared to 6 miles outside the area, was about 57% on untreated tobacco fields. There were also some indications that light traps reduced the corn earworm populations.

At Quincy, Fla., light traps were placed around and inside a 7-acre shade of cigar wrapper tobacco. Twelve traps with four 32-watt circline lamps were placed about 50 feet from the shade on all 4 sides and spaced 160 feet apart. Five omni-directional traps with fan were placed inside the shade, one in each corner and one in the center. Di-Syston was applied in the drill at 4 pounds per acre at transplanting time for aphid and flea beetle control. Subsequent treatments were one application of insecticide for flea beetles and in replicated plots in the field one application of

polyhedrosis virus alone, Bacillus thuringiensis alone, and a combination of the two pathogens at 1/2 the usual dosage for tobacco budworms. Budworms collected from each treatment indicated that B. thuringiensis was the better and faster acting pathogen, although the virus gave a 60% kill of collected larvae. The combination of the two agents gave the lowest kill. In this 7-acre shade with light traps only 2 insecticide applications were made for all insects compared with 17 applications in a 10-acre shade area without light traps. The percent leaves damaged by budworms and the cabbage looper ranged from 0.5 to 2.7 in the light-trap shade compared with 1.0 to 3.5 in the shade without light traps.

At Florence, S. C., 3-day old virgin tobacco hornworm females were better sources for extracting sex attractant than younger females. This was also confirmed at Oxford when 2- to 4-day old virgin females showed greatest attraction to males when used in combination with light traps.

At Oxford, N. C., virgin female hornworm moths placed near light traps greatly increased the catch of male hornworms. For every 94 male moths caught by the light trap alone, the addition of each female up to 10 increased the male catch by 89.

In a cooperative test with the Agricultural Engineering Research Division, 3 light traps per square mile are being established on the Island of St. Croix to test the feasibility of total population control of the tobacco hornworm.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Lawson, F. R., and R. L. Rabb. 1965. Factors controlling hornworm damage to tobacco and methods of predicting outbreaks. Tobacco Sci. 8: 145-9.

Insect Sterility, Attractants, and Other New Approaches to Control

Gentry, C. R., F. R. Lawson, and J. D. Hoffman. 1964. A sex attractant in the tobacco budworm. J. Econ. Entomol. 57: 819-21.

Insecticide Residue Determinations

Lawson, F. R., Calvin Corley, and M. S. Schechter. 1964. Insecticide residues on tobacco during 1962. Tobacco Sci. 8: 110-2.

AREA NO. 11. SUGARCANE AND SUGARBEET INSECTS

Problem. Control of insects on sugarcane and sugarbeets is essential because of destructive plant diseases spread by insects and damage caused. The use of insecticides for insect control requires special care to avoid contamination of the harvested product with undesirable residues. Safe effective methods of control are especially needed for the sugarcane borer, the sugarbeet root maggot, and the beet webworm. Sugarcane mosaic has become more important in recent years, and information on insect vectors of this disease is needed. Beet yellows and associated western yellows virus diseases of sugarbeets continue to threaten the sugarbeet industry. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. Studies on the ecology and methods of control of the weed reservoirs of the insects that transmit the two viruses should be continued. For long-range solutions to these problems, further investigations should be undertaken to find effective parasites and predators of sugar-crop pests and to develop varieties of sugarcane and sugarbeet that are resistant to insect attack. The usefulness of destruction of alternate host plants and new approaches to insect control, such as the male sterility technique and attractants, should be investigated. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make the natural control of other pests on the same crops difficult are special problems that should receive emphasis in the search for nonchemical methods of control.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. This program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway and with industry. Studies on sugarcane insects are conducted at Houma, La., Canal Point, Fla., and Mayaguez, Puerto Rico; and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, Logan, Utah, and Yakima, Wash. A research grant has recently been negotiated with Louisiana State University to investigate the factors affecting the efficiency of Trichogramma spp. as parasites of lepidopterous pests.

The Federal scientific effort devoted to research in this area totals 8.9 professional man-years. Of this number 1.5 is devoted to basic biology, physiology, and nutrition; 2.2 to insecticidal control; 0.6 to insecticide residue determinations; 1.5 to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; 0.2 to evaluation of equipment for insect detection and control; 0.6 to varietal evaluation for insect resistance; 1.1 to insect vectors of diseases; and 0.6 to program leadership.

In addition Federal support of research in this area under a grant provides for 0.3 professional man-year devoted to biological control.

In addition, natural enemies of the sugarcane borer in India are being studied under a PL 480 research grant, Project A7-ENT-1, by the Commonwealth Institute of Biological Control, Bangalore, India. Parasites and predators found effective for borer control will be made available for use in the United States.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in the States on insects affecting sugar production is concerned with disease transmission, biological studies, and control.

On sugarbeets, studies are in progress on both curly top and yellows disease. Fields and desert breeding grounds are sampled to determine the population levels of insect vectors. The influence of date of planting, plant resistance, and other control practices such as foliar and seed applications of systemic insecticides are being evaluated for their effectiveness in reducing disease incidence.

The ecology of other insect pests of sugarbeets is also under investigation. Variations in temperature and other natural phenomena are being correlated with seasonal development. Records are obtained of overwintering sites, time of appearance in the spring, oviposition, pupation, emergence of late generations, host preferences, and the effects of various hosts on development.

Similar biological studies are being conducted on insect pests of sugarcane. In addition insecticides and other agents are being evaluated for their effectiveness in control. The identity and importance of natural enemies and the effects of insecticides on beneficial species is being determined. Variations in responses of plants to insect attack are also under investigation. Survey methods are being developed to obtain a more accurate estimate of losses caused by insect attack.

Scientists are investigating the possibilities of control of the sugarcane borer by radiation. Mass rearing methods are being developed and various life stages of the insect subjected to gamma radiation to determine the levels necessary for sterilization. Light of different wave lengths and chemicals are being investigated to determine their usefulness as attractants to the sterilization source.

In all, 6.3 professional man-years are dedicated to research on insects affecting sugar production in the States.

A. Basic Biology, Physiology, and Nutrition

1. Sugarbeet Insects. The spinach leaf miner caused as much as 50% defoliation in some Washington fields, yet studies indicated only 12% of the eggs resulted in mature larvae. Eggs were distributed uniformly within sugarbeet fields. In one field 99.9% of the leaves were infested with eggs on May 14. Eggs were deposited on the underside of leaves but the larval trails and blotch mines formed within the leaves were most distinct from the top side. Eggs were laid singly, in pairs, and in clusters of 5 or more. As many as 75 eggs were found on a single leaf. The trail mines of the larvae often converged but seldom was more than 1 large larva found in a blotch mine.

The relatively new ephydrid leaf miner pest, Psilopa leucostoma Meig., continued to spread through eastern Washington. It threatened to cause more damage than the spinach leaf miner by attacking the plants later in the growing season and leaving open mines subject to secondary infection by bacteria.

Winter temperature and snow cover continued to be important factors in the location and extent of overwintering of the green peach aphid and its importance in spreading yellows virus. In severe winters the aphid usually survives only in the egg stage on peaches and the spring migration to and propagation on sugarbeets is restricted to areas near orchards. In mild winters, however, the summer forms that produce only living young also survive on weeds throughout the sugarbeet area and the spring colonization on sugarbeets is usually more uniform and the spread of virus diseases much greater.

Heavy applications of nitrogen fertilizer, particularly when sidedressed on beet plants more than half grown, tended to mask typical symptoms of beet western yellows and to prevent reductions in yield.

Lygus lineolaris and related species migrated from hoary cress (Lepidium draba), tumblemustard (Sisymbrium officinale), and other weeds to sugarbeet in June and July where several types of damage were observed. Adult feeding punctures of leaf petioles caused conspicuous galls. Punctures in the rapidly growing mid-ribs of the leaves depressed growth and caused the leaf tips to become yellow and gnarled, frequently resembling symptoms of beet western yellows. Nymphs tended to congregate in the crowns of the plants where extensive feeding caused plant sap to accumulate, ferment, and form a sticky brown deposit.

Sugarbeet root maggots collected in fields near Twin Falls, Idaho, and held in the greenhouse began maturing on May 11, 1965. Adults were observed in beet fields and also collected in bait traps on May 12. Field observations revealed the presence of maggot eggs on the crowns of young beets on May 24. Sugarbeet juice was more attractive in sticky board bait traps to the adults than young sugarbeet plants, sugarbeet roots, beet molasses, or 5%

sugar solution. Also, black was more attractive than green, white, yellow, and unpainted wood. The most flies were collected on the south side of the sticky board traps.

2. Sugarcane Insects. The annual 1964 harvesttime survey to determine degree of sugarcane borer infestation and crop loss in Louisiana showed 11% of the joints (internodes) of sugarcane bored with an estimated crop loss of 8%. The 1965 first-generation infestation in terms of borer-killed, dead-heart plants showed an estimated average of 2,743 borer-killed plants per acre. This is five times the 1964 average of 549 and 73 times higher than the 1962 average of 38. In Florida an average of 6% of the joints were bored, but in the Fellsmere area the average was 13%. In Puerto Rico infestations of the sugarcane borer remained about normal, averaging from 6 to 9% joints bored depending upon locality. The lesser cornstalk borer, fall armyworms, and the sugarcane aphid also caused damage to sugarcane in Puerto Rico. Although white grubs and wireworm infestations were of little economic importance in Louisiana, the latter caused almost complete stand failures in the sugarcane sirup area of Grand Bay, Alabama.

The white-fringed beetle caused considerable damage to sugarcane in the sirup area near Mobile, Alabama. The stand and growth of the plants were impaired by the larvae injuring the underground portions of the stubble and roots during the early growing season. As many as 9 larvae were found infesting the new growth in one 6-square-inch sample of sugarcane stubble.

The southwestern corn borer, reported to be a pest of sugarcane in some areas of Mexico, was found near sugarcane fields in Louisiana, but none was found in the fields examined.

A new antibiotic system based on Tegosept and Hyamine 1622 (Di-isobutyl phenexy ethoxy ethyl dimethyl benzyl ammonium chloride, monohydrate) has been successful in eliminating contamination in semi-artificial sugarcane borer diet. Tegosept at 1.5 grams and Hyamine 1622 at 3.0 grams are blended with 500 grams of sugarcane tops and joints, 50 grams of a high protein base, 10 grams of ascorbic acid, and 750 milliliters of water. After blending to a coarse consistency, excess liquid is pressed out with a potato ricer, leaving sufficient residual antibiotic to control fungi completely. With this diet large numbers of sugarcane borers can be reared for laboratory testing.

B. Insecticidal and Cultural Control:

1. Sugarbeet Insects. One pound of phorate, applied as 10 pounds of 10% Thimet granules, per acre with aircraft in Washington to sugarbeets infested with the two-spotted spider mite, gave 97% control for 29 days and 93% control for 49 days. A 10% granular Di-Syston formulation applied in the same manner was not effective.

The seasonal control of the green peach aphid on sugarbeets increased as the number of applications of demeton, dimethoate, phosphamidon, and Meta-Systox sprays applied with aircraft increased from 2 to 6. The spread of beet western yellows virus, carried by this insect, also declined as aphid control increased. Demeton and Meta-Systox gave best control. All treatments increased yields, and in 1 field 6 tons more beets were harvested from the demeton plots than from the check plots.

Yield records obtained from 50 Walla Walla, Wash., beet growers in the fall of 1964 showed that 30 growers who made 1 application of 10% Di-Syston granules at 10 lb/acre in May to prevent the green peach aphid from spreading beet western yellows harvested an average of 17.6 tons of beets per acre, or 15% more than growers who did not apply insecticides.

Satisfactory control of the spinach leaf miner was obtained with single applications of sprays containing one-half pound of Dylox or Meta-Systox, or one pound of Phosphamidon or Di-Syston in 30 gallons of spray per acre with a row-crop sprayer. Larvae were found more susceptible than eggs to the treatments. Preliminary observations indicated that 10 pounds of 10% Di-Syston granules at 10 pounds per acre dribbled on the infested beets was less effective than Di-Syston spray.

Laboratory and greenhouse screening tests at Twin Falls, Idaho, on 55 candidate insecticides for slurry seed treatments to control the beet leafhopper showed only 12 worthy of field tests. In subsequent field tests only phorate reduced leafhopper spread of curly top as much as 40%.

In an experimental field planting of pelleted sugarbeet seed by the Logan, Utah, station, dimethoate at 8 ounces or phorate at 3 ounces per acre reduced the beet leafhopper population 84% on plants in the 8- to 12-leaf stage of development. The seeds were first coated with blood-protein complex to prevent phytotoxicity before being pelleted. In greenhouse tests dimethoate added to pelleted sugarbeet seed at 7 ounces per acre gave 100% mortality of beet leafhoppers caged on plants in the 2-leaf stage.

Of 33 materials screened in the laboratory at Twin Falls, Idaho, 17 were as toxic to beet webworm as DDT and trichlorfon used as standards, but all except Kepone are experimental materials as yet not available to growers.

Sugarbeet yields were not increased by use of insecticides for the control of the sugarbeet root maggot at Twin Falls, Idaho, even though the population of this insect was decreased by some materials. Sixteen insecticides were applied as granular formulations in the drill row at planting time or incorporated into the seedcoat of pelletized seed. Considering both the maggot count and yield, ethion, carbophenothion, schradan, stabilized phorate, V-C 13, and Stauffer 2790 showed enough promise to justify further testing.

In root maggot and symphylan experiments in Utah, pelleted sugarbeet seed containing dimethoate at 3 ounces per acre improved the emerged stand of unthinned beets 12% and increased the yield 0.8 ton per acre in one field and 4.4 tons in another. Seed coated with blood-protein complex to prevent phytotoxicity and pelleted with phorate at the rate of 3 ounces per acre increased the emerged stand by 30% and the thinned stand 12% over the untreated checks. This treatment increased the yield of sugarbeets 0.7 ton per acre. Di-Syston added to the pelleted seed at 1.5 ounces per acre reduced symphylans 43%, increased the stand of plants 29%, and increased the yield of beets 3.1 tons per acre. In other tests, however, at double the dosage of Di-Syston the stand of plants was reduced.

Lygus bug damage to sugarbeets grown for seed in Utah was controlled by dimethoate spray applied when the plants were in the prebud and flowerbud stage of growth. The viability of the harvested seed was 94% in the sprayed plots as compared to 88% in unsprayed check plots. The emulsion contained 10% of molasses. Dimethoate without molasses was less effective. Naled emulsion also was less effective.

2. Sugarcane Insects. Endrin has been recommended for control of the sugarcane borer in Louisiana since 1958. In 1962 it became apparent that borer resistance to endrin had developed at several locations. This insecticide gave an average control of only 51% in three widely separated locations in 1964. Since 1962 an effort has been made to find new insecticides to control the borer. Large-plot aerial tests with endrin, Guthion, methyl-ethyl Guthion, carbaryl, endosulfan, diazinon, and parathion all applied in a granular form were conducted in 1964. Guthion gave the best control. Control with both endrin and endosulfan, which formerly gave good control, was relatively poor, indicating that sugarcane borers are resistant to these insecticides. Diazinon gave fair control but was toxic to predaceous and saprophytic arthropods.

In Florida on muck soil infested with wireworms, treatments with phorate at 2 pounds per acre, heptachlor at 4 pounds, and Telodrin at 2 pounds per acre all gave increase in yield of sugarcane of more than 5 tons per acre.

During recent years in Louisiana, chlordane has been widely used in sugarcane fields for control of wireworms and small soil arthropods. Since there is a possibility that repeated applications of the insecticide might create a phytotoxic condition in the soil, a large-plot experiment to study this possibility was initiated in 1958. Seven alternate cuts planted in sugarcane variety N.Co. 310 were treated that year and again in the fall of 1963 when the experimental area was replanted with variety C.P. 44-101. Yield data obtained for three crops following the first chlordane application revealed no phytotoxic effects. None of the differences for any of the three years were statistically significant.

Chlordane applied to seed pieces at planting time in wireworm and white-fringed beetle infested fields increased sugarcane stands. At Grand Bay,

Alabama, chlordane at 3 lb/acre applied in a 25 acre field planted with sugarcane varieties C.P.'s 29-116 and 36-111 in late September increased stands by 25%.

C. Insecticide Residue Determinations

1. Sugarbeet Insects. Objectionable drift of insecticides were observed when experimental applications of sprays and granules drifted from the target areas in Washington. In one instance, 50 ppm residue of an organic phosphate insecticide was found on alfalfa 50 feet inside a field several days after an adjoining beet field had been sprayed. In this case the residue resulted from spray that was carried off target in the slipstream of the aircraft as it pulled up out of the beet field. In another case, 2 ppm residue was found on alfalfa 75 feet and 0.1 ppm as far as 340 feet from the edge of a beet field following an aircraft application made with a cross-wind in excess of 5 mph. In the third case, granules of an organic phosphorus insecticide applied by aircraft with a cross-wind of 3 mph drifted 179 feet from a beet field.

Demeton residues on filter-paper squares placed in a plot of sugarbeets receiving 5 aircraft applications of demeton at 1 pound in 9 gallons of spray per acre showed that approximately 25% of the demeton impacted within the plot. Demeton recovery across the plot ranged from 0 to 0.82 ppm in samples taken immediately after the last application. The average demeton residue found on the leaf surfaces was 33 to 53% lower than that found in the filter papers put in the field before spraying. The average deposit on the foliage ranged from 6.0 to 7.3 micrograms of demeton per square inch and that on comparable filter paper from 9.9 to 12.7 micrograms per square inch.

Six aircraft applications at 2-week intervals of demeton, Meta-Systox, and phosphamidon at 1 pound active material in 9 gallons of spray per acre left no objectionable residues in the leaves 43 days after the last application.

Di-Syston or phorate granules (10%) were applied to sugarbeet plots by fixed wing aircraft at the rate of 1 pound of actual insecticide per acre. Samples of foliage, crowns, and roots harvested 51 days after application showed Di-Syston residues of 0.08 and 2.99 ppm on the foliage, 0.08 and 6.27 ppm on the crowns, and 0.09 and 0.08 ppm in the roots. Samples from the phorate plots showed residues of 0.35 and 0.57 ppm in the foliage, 2.60 and 1.68 ppm in the crowns, and less than 0.04 ppm in the roots.

In studies of organic phosphates at Yakima, Wash., no measurable residues were detected in roots or crowns of sugarbeet plants 116 days after an application of Bayer 39007 granules at 2.5 lb/acre in an 8-inch band on top of the plants, or 97 days after a similar application of phorate, or a 1-2-2 mixture of dimethoate, phorate, and schradan. The Bayer 39007 left a residue of 0.05 ppm on the foliage. The phorate treatment left no residue on the foliage. The mixture left a foliage residue of 0.16 ppm

calculated as schradan and attributed to schradan. In similar studies with sprays applied to the foliage 97 days before harvest, demeton or phorate at 1.2 lb/acre left no residues on the leaves, crowns, or foliage. A spray mixture of equal parts demeton and schradan left 0.17 ppm on the foliage. A spray mixture of equal parts of phorate and schradan left 0.16 ppm on the foliage calculated as schradan and attributed to schradan.

D. Biological Control

1. Sugarcane Insects. Investigations directed toward finding new and effective parasite species against the sugarcane borer were continued. Ten species that attack sugarcane borers in India were obtained through PL 480, A7-ENT-1 for study in the laboratory at Canal Point, Florida. Three of these, Apanteles flavipes, Stenobracon deesae, and S. nicevellei displayed sufficient potential to justify rearing and releasing in commercial fields.

Observations were continued in southern Florida to ascertain more precisely the role and importance of the presently existing biological entities toward reducing the sugarcane borer population. Agathis stigmatera Cress. parasitized an average of 15.9% of the borer population during 1964. Late instar larvae and pupae mortality averaged 22% as a result of earwig (Dermaptera) predatism during the months of August through October, 1964. Trichogramma fasciatum Perkins egg parasitism during the late summer and early fall ranged as high as 96% in some parts of the Everglades.

Fall parasitization of sugarcane borer by the Cuban fly, Lixophaga diatraeae, was as high as 40% in one field on a plantation in Louisiana where the last releases were made in 1956. This tropical parasite has survived two of the recent coldest winters of this century and also the commercial application of insecticides for borer control in Louisiana.

Studies in Puerto Rico indicate that Cuban fly parasitization is apparently density-dependent. When sugarcane borer population density is high, all life stages of adequate size are parasitized at an almost equal rate. This contrasts with parasitization of approximately double the number of third and fourth instar larvae compared with fifth and sixth instar when parasite population densities are low. In Puerto Rico, high parasite population densities seldom appear because of an apparently excellent balance between parasite and host. When environmental conditions are such that borer numbers are encouraged or parasite numbers are reduced, a population explosion of borers occurs with consequent upswing of parasitization rate until normal balance are reestablished.

Stenocranophilus quadratus and Anagrus armatus, two parasites introduced into southern Florida in 1959 from Jamaica, are currently holding the population of the West Indian sugarcane delphacid at a low level.

S. quadratus, now found throughout the Florida sugarcane area, was found parasitizing an average of 36% of the pests in 68 of 72 fields sampled during December-January, 1964-65. A. armatus was recovered in fields over 40 miles from the 1959 release site and was found in 48 of 97 fields examined.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Borer. In Puerto Rico aziridine and uracil compounds which are effective chemosterilants for some insects caused high mortality when tested against sugarcane borer moths.

Sex attractant studies have suggested that the sugarcane borer female pheromone is not a primary long-range attracting stimulus but is probably essential for copulation initiation and possibly as a means of close-range male orientation with females. Darkness alone stimulates general male activity. Extirpation of the antennal flagellum of males precludes mating but does not interfere with general activity in darkness. In the laboratory continuous light was found to completely suppress mating activity of the sugarcane borer, even when the favorable two male for one female sex ratio was used. Further studies exploiting this new approach to insect control have shown that intermittent applications of light, 10 seconds per five minutes, suppresses almost all mating activity. High intensity flash treatments at 10 second intervals for five minutes also disrupt mating activity. However, a normal sugarcane borer infestation developed in lighted field plots which were many times lighter than the amount of darkness required for mating.

F. Varietal Evaluation for Insect Control

1. Sugarbeet Insects. No preference was shown by the green peach aphid for any of 25 varieties and selections of sugarbeet tested in Washington.

2. Sugarcane Insects. Of 281 sugarcane varieties tested in hand-infested plots in Louisiana, 41% had a lower percentage of joints bored, and 46% produced more sugar per acre than standard variety C.P. 36-105. Thirty-seven varieties of sugarcane consisting of one control variety, one new commercial variety, and 34 unreleased varieties were field-tested under two levels of borer infestation in 1964 to obtain information on their relative tolerance. Varieties C.P. 61-90, C.P. 58-48, L. 61-40, L. 61-41, and C.P. 61-43 showed a loss of less than 13 pounds of sugar per acre for each 1% joints bored. The greatest losses, ranging from 61 to 75 pounds for each 1% joints bored, were shown by varities L. 61-52, L. 60-25, L. 61-9, L. 60-12, and C.P. 36-105.

H. Insect Vectors of Diseases

1. Sugarbeet Insects. In the Salt River Valley of Arizona, plots of sugarbeets grown for seed under conditions of high, intermediate, and low fertility were infested with virus yellows infective green peach aphids and seed yields compared to similar plots maintained aphid-free. Plots were arranged in a 6x6 latin square. The level of nitrogen fertilizer in those plots designated as "Intermediate" was similar to that used by the average beet seed grower. The nitrogen level of the "High" plots was approximately double that of the "Intermediate" plots, while the "Low" plots received less than half of the total nitrogen of the "Intermediate" plots. Results showed that under virus yellows-free conditions the fertilizer program of the average beet seed grower in the Salt River Valley is adequate and nothing is gained by additional applications of nitrogen fertilizer. However, if the crop is likely to be subjected to heavy infestations of virus yellows infective aphids, part of this loss can be averted by additional applications of nitrogen fertilizers.

In Washington losses in yields in sugarbeet plants that were tagged in a sugarbeet field and naturally infected with yellows viruses were 46% on early-infected plants and 33% on late-infected plants. Similar losses were obtained when caged plants were infested by hand with viruliferous aphids for 1 week and the aphids killed. The yield of beets infested May 5, May 22, and June 12 was reduced 46%, 37%, and 25%, respectively.

Greenhouse tests at Yakima, Wash., showed that at least 28 local species of wild and cultivated plants belonging to 7 different families served as alternate hosts of beet western yellows. Most important of these were several perennial, biennial, or fall-sprouting annuals in which the disease can overwinter in the field. Infected beets, which can survive most winters in the Pacific Northwest, were found capable of overwintering beet yellows, as well as beet western yellows and beet mosaic.

Yield data obtained from growers who continuously grew beets for several consecutive years showed that after the second year yields declined sharply. Part of this reduction, at least, was caused by a gradual increase in yellows in alternate host plants near these fields facilitating spread by the green peach aphid.

Although larger populations of the green peach aphid developed on sugarbeets in fields near peach orchards than elsewhere, the incidence of beet western yellows carried by this insect was greater in fields near deep, drain ditches and other ecological niches in which the summer forms of the aphid and virus-infected alternate host plants overwintered successfully.

Summer forms of the green peach aphid overwintered successfully on hoary cress (Lepidium draba), sowthistle (Sonchus sp.), curly dock (Rumex crispus) in protected locations of eastern Washington during the mild winter of 1963-64 and also apparently on spinach and shepherds-purse (Capsella Bursa-pastoris) in

unprotected places. However, during the cold winter of 1964-65 they also overwintered on hedge glorybind (Convolvulus sepium) in protected locations. Irrigation drains were particularly favorable locations for overwintering of the aphids.

2. Sugarcane Insects. Mosaic disease continues to be a problem of great economic importance in sugarcane production in Louisiana. Since the disease is spread by insects, it seems logical that an appreciable reduction in mosaic spread could be attained if the vector population could be effectively controlled. In a 22.62-acre plant cane block of two disease-susceptible varieties, C.P.44-101 and C.P.52-68, treated with demeton in the fall and spring, percentages of mosaic reduction in June were 30 in the latter and 64 in the former variety. Control of vectors ranged from 82 to 100%. Malathion + heptachlor, Di-Syston, dimethoate, phorate, demeton, and diazinon were evaluated as disease-vector controls. All chemicals gave a 100% control of the rusty plum aphid (Hysteroneura setariae), the only species recorded for which sugarcane is a natural host. Dimethoate and phorate reduced mosaic spread by 20% each, and malathion plus heptachlor and diazinon showed reductions of 25 and 38%, respectively. None of the materials showed any phytotoxic effects.

Although sugarcane is not a natural host for the corn leaf aphid, studies showed that the insect can be cultured on sugarcane plants. Sugarcane mosaic transmission tests with the bean and cowpea (Aphis craccivora) and the southern corn rootworm (Diabrotica undecimpunctata howardi), 2 insects prevalent in sugarcane fields, gave negative results.

Vector-virus relationship transmission studies in cooperation with pathologists with the corn leaf aphid showed that (1) the insect became viruliferous within 5 minutes after being placed on mosaic-infected sugarcane plants, (2) viruliferous insects transmitted mosaic within 15 minutes after being placed on healthy sugarcane plant, (3) the insect apparently lost the ability to transmit mosaic within 1 hour after being removed from diseased plants, and (4) there was a difference in mosaic transmission between insects cultured through several generations on mosaic-infected sorghum and those cultured on mosaic-infected sugarcane plants for 24 hours prior to being transferred to healthy test plants. Similar studies with the brick-red sowthistle aphid indicated that this aphid (1) also became viruliferous within 5 minutes after being placed on mosaic-infected sugarcane plants, (2) transmitted the virus within 5 minutes after being placed on healthy plants, (3) remains viruliferous for only a short time, (4) can transmit the virus to more than one plant, and (5) loses ability to transmit mosaic after feeding on healthy plants for 1½ hours. These studies show that the sugarcane mosaic virus is non-persistent; it does not require a latent period before being transmitted, and the vector remains infective for only a short period.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Charpentier, L. J., W. J. McCormick, Ralph Mathes, and J. W. Sanford. 1965. Borer infestation and loss in the 1964 sugarcane crop. Sugar Bull. 43: 215-18.

Miskimen, G. W. 1964. Crianza del borer de la cana en el laboratorio Bol. Azucar Mexicano 185: 15.

Miskimen, G. W. 1965. Nonasepteic laboratory rearing of the sugarcane borer, Diatraea saccharalis. Ann. Entomol. Soc. Amer. 57(6): In Press.

Insecticidal and Cultural Control

Suggested Guide for the Use of Insecticides to Control Insects Affecting Crops, Livestock, and Households for 1965. USDA Agr. Handbook No. 290 (R): 26.

1965 Recommendations for Sugarcane Insect Control. Louisiana Agr. Ext. Serv. Insect Control Guide for 1965. 58-61.

Dorst, Howard E. 1965. Insect control on sugarbeets by seed or soil treatments. J. Amer. Soc. Sugarbeet Technolog. 13.

Onsager, J. A. and B. J. Landis. 1964. Insecticides and application times for wireworm control. The Packer. 12-5-64, p. 12.

Onsager, J. A. and B. J. Landis. 1964. Careful timing all-important in controlling wireworms. Washington Farmer 90: 16.

Biological Control

Gifford, J. R. 1965. Goniozus indicus as a parasite of the sugarcane borer. J. Econ. Entomol. In Press.

Gifford, J. R. 1964. A brief review of sugarcane insect research in Florida, 1960-64. Proc. Soil and Crop Sci. Soc. of Florida. In Press.

Insect Sterility, Attractants, and Other New Approaches to Control

Miskimen, G. W. 1965. Effects of light on mating success and egg laying activity of the sugarcane borer, Diatraea saccharalis (F). Ann. Entomol. Soc. Amer. Accepted for publication.

Insect Vectors of Diseases

Charpentier, Leon J., and Natale Zummo. 1964. Field experiments with insecticides for control of insect vectors and sugarcane mosaic spread. Sugar 27: 17-19.

Coudriet, D. L. 1964. Migrant green peach aphids and the spread of yellows viruses in seed beet fields of Arizona. J. Econ. Entomol. 57: 939-40.

Zummo, Natale, and Leon J. Charpentier. 1964. Vector-virus relationship of sugarcane mosaic virus. I. Transmission of sugarcane mosaic virus by the brick-red sowthistle aphid, Dactynotus ambrosiae Thos. Plant Dis. 48:636-39.

AREA NO. 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites. They are also damaged by a variety of diseases spread by insects. More effective and safer control measures are needed for many of these pests. Knowledge of the basic distribution of insect pests of these plants and information on their biology are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable residues are needed. The nature and cause of resistant strains of insects and mites and means of overcoming or preventing their resistance to insecticides require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological control with insecticidal and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be studied. Increased emphasis should be placed on the search for insect attractants, chemosterilants, and growth or reproduction-affecting substances.

USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N. Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N. J., and Geneva, N. Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and Agricultural Engineering Research Divisions of ARS. Research on turf insects is also conducted under grant with the University of Florida.

The Federal scientific effort devoted to research in this area totals 8.4 professional man-years. Of this 1.4 man-years are devoted to basic biology and nutrition; 1.8 to insecticidal control; 1.0 to insecticide residue determination; 0.7 to biological control; 2.4 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.4 to insect vectors of diseases; 0.1 to insect control treatments for commodities regulated by plant quarantine; and 0.5 to program leadership.

In addition Federal support of research in this area under grant provides for 0.4 professional man-year devoted to basic biology.

PROGRAM OF STATE EXPERIMENT STATIONS

The research program in the States on insects affecting ornamental shrubs, flowers and turf is providing valuable information. Surveys are being conducted to determine the occurrence and abundance of insects and mites and their natural enemies. Investigations are underway to evaluate the extent and amount of damage caused by injurious species. Studies of seasonal life histories form a basis for developing practical control measures. Insects are reared in the field and collected for laboratory observation on the duration of life cycles in relation to temperature and other environmental factors. This information is used to determine which types of control methods would be used for most satisfactory results.

Principal emphasis is placed on chemical controls due to (1) the sporadic nature of insect and mite attacks on many ornamental plants; (2) the need for extremely effective control in nurseries to prevent dissemination of pests; and (3) the comparatively permanent nature of plantings of most ornamentals and turf grass which prevents the use of many cultural control methods. As new chemicals become available, they are evaluated for safety phytotoxicity and effectiveness in controlling injurious insects. Various formulations, schedules, concentrations and application rates are tested. Recently, increasing emphasis is being placed on the use of systemic insecticides on ornamentals because of their greater ease of application and reduced environmental toxicity hazard.

Resistance of certain mite species to control chemicals also is being studied. The incidence and degree of resistance is being determined, and the morphology and physiology of affected strains of mites studied to identify the factors responsible. Biochemical methods are being employed to determine differences in physiological systems not observable in behavior and morphological studies.

The State stations are devoting 19.6 professional man-years to the research in this area.

A. Basic Biology, Physiology, and Nutrition

1. Orange Tortrix. At Sumner, Wash., orange tortrix males and females caged individually without food or water lived an average of 11 and 13 days, respectively. When given access to a 5% sucrose solution, the life span was increased by 6 days for the males and 3 days for the females. When single laboratory reared virgin males were caged with 1, 2, 3, and 4 virgin females, the bursa copulatrix yielded 2, 2, 5, and 6 spermatophore, respectively, indicating multiple mating had occurred in both sexes.

2. Japanese Beetle. Clear polyethylene bags (8" x 15½") were suitable containers for rearing grubs in New Jersey. One thousand grams of soil placed in each bag could maintain 50 to 75 third-instar grubs. Wheat was satisfactory as a food, providing more roots for feeding large grubs than

red-top clover mixtures. Third-instar grubs collected from the field were successfully reared to the adult stage with wheat roots as food; newly hatched grubs were reared to the second-instar. A medium of sterilized soil, peat moss, and peat moss with vermiculite seeded with red-top clover has given a 90% survival of grubs to the second instar.

A screened cage was developed which facilitiates collection of eggs, cleaning and storing, and permits the use of plants as food sources. Giant smartweed foliage has proven to be an excellent host plant for maintaining caged adults, and preferred to the fruits of plum, peach, and apple formerly used. Caged adults did not feed on asparagus foliage or plants and fed only sparingly on rhubarb.

3. European Chafer in New York. Seven and one-half percent of larvae reared in soil seeded with rye grass and clover that was watered daily transformed to adults. One hundred first-instar larvae were obtained from 136 reared adults. Chafers remain in the third instar 260 days in nature; are dormant 70 to 80 days of this period. In the laboratory this period was reduced to 168 days and adults emerged in mid-April instead of mid-June. No diapause was encountered.

4. Pentac Useful in Insect Culture. In Maryland, Pentac controlled spider mites on host plants used to rear the omnivorous leaf roller, Platynota stultana, without damage to the leaf roller. Spider mites often cause rapid decline of host plants before leaf roller larvae can mature, thus interferring with biological studies. In tests of acaricides with low insecticidal activity for protecting the host plants from spider mites, Pentac, binapacryl, and Morestan each in sprays at 0.5 lb/100 gal had no apparent effect on half-grown leaf rollers reared to maturity on the sprayed plants. However, 98% of newly hatched larvae accepted Pentac-sprayed plants compared to 90% on untreated, 56 on binapacryl, and 80 on Morestan. Binapacryl exhibited a repellent effect with reduction in larval feeding and Morestan a slight toxic effect with smaller, less active larvae. Pentac appears to be the preferred differential acaricide, and will doubtless be useful in the laboratory rearing of other insects.

B. Insecticidal and Cultural Control

1. Zectran Controls European Corn Borer on Rose. In Maryland conventional fumigants and hand cutting failed to prevent severe losses caused by the feeding of this insect in stems and flowers of greenhouse roses. Zectran at 6 ounces per 100 gallons of emulsion spray gave excellent control. Larvae in tunnels were killed when they came in contact with residue around the tunnel entrance.

2. Poinsettia Insecticides. In Maryland weekly applications of dichlorvos aerosol were effective against whiteflies, soft scale, citrus mealybug, and Lewis mite. Weekly applications of binapacryl wettable powder spray controlled spider mites. Single applications of Meta-Systox-R emulsion gave

general protection against insects and mites. The materials were effective without leaving objectionable residues or causing injury to these highly sensitive plants that are injured by most insecticides.

3. Phytotoxicity Traced to Solvents in Insecticide Formulations. Severe growth-regulator injury or necrosis and chlorosis on chrysanthemums, poinsettias, and petunias sometimes follow the application of commercial preparations of dichlorvos, diazinon, Di-Syston, or Meta-Systox-R in thermofogs, mechanical fogs and mists, or conventional sprays. Investigations in Maryland disclosed that plant injuries can be reproduced by certain accessory materials present in the formulations. In tests with mechanical fogs certain methylated naphthalenes alone or combined with dichlorvos caused severe growth-regulator injury on susceptible chrysanthemums. A highly refined kerosene (Deobase) alone caused severe necrosis on Shasta chrysanthemum and lima bean. Methylene chloride formulations with dichlorvos caused no injury to the same crops. Results of these tests are influencing commercial formulators of greenhouse insecticides to modify their products.

4. Japanese Beetle. Field tests in North Carolina made by the Moorestown, N. J., laboratory indicated that control of Japanese beetle grubs in sod can be obtained with 8 pounds of diazinon per acre.

5. Tulip Bulb Aphid Controlled on Iris. In greenhouse tests in Washington, Meta-Systox-R and dimethoate applied at 2 pounds per 6-inch acre to iris bulbs when planted in flats gave excellent control of the tulip bulb aphid.

6. Spider Mites on Roses. In foliage sprays applied to outdoor roses at Beltsville, Kelthane, binapacryl, and dimethoate were superior to Pentac against nonresistant mites. Against resistant mites Kelthane and binapacryl were also highly effective but dimethoate failed to give control and was about equal to Pentac. The addition of 2% dimethyl sulfoxide to the four acaricide sprays provided no consistent enhancement of toxicity or persistence of effectiveness.

C. Insecticide Residue Determinations

1. Benzene Hexachloride Residues in Soil Toxic After 7 Years. This insecticide was applied annually at 16 pounds gamma isomer per acre for 5 years ending in 1957 in New York plots. Snapdragons planted 7 years later were reduced 22% in growth by the residues still present in comparison with snapdragons grown in replicated untreated plots. Double this dosage of gamma isomer applied as lindane did not affect growth. The insecticide residues tended to increase the growth of carnations.

D. Biological Control

1. Plant Traps Insects. Araujia sericifera, a climbing vine native to Brazil and Argentina, is grown throughout the world as an ornamental and

sometimes to catch insects. Captures at Beltsville, Md., in the flowers of this plant included 14 species of Lepidoptera mostly cabbage looper, corn earworm, tobacco budworm, and the alfalfa looper, and numerous ants and an occasional honeybee. The moths, when feeding on nectar in the flowers, are caught when the proboscis becomes wedged between a pair of finger-like processes at the base of each stamen.

Observations at night by flashlight indicate that flowers of this plant are not highly efficient moth or insect catchers since only a small proportion of the insect visitors are captured. However, the flowers are highly attractive to many species of economic pests especially noctuids, even in presence of Jimson weed, tobacco, and petunia. The flowering plants or the flower extracts may be of value as a decoy in connection with use of sterilants, poison baits or black light traps.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Orange Tortrix. In further studies at Sumner, Wash., a crude sex lure was extracted from copulating moths with methylene chloride. When a trap containing a filter paper impregnated with 100 female equivalents was placed in a 2 x 3 foot cage containing 25 3-day-old virgin males, 21 percent of the males were caught in 40 hours. Studies on the purification of the sex lure have been initiated.

2. Japanese Beetle. At Moorestown, N. J., it was found that tepa-treated beetles released in the field soon after treatment will not augment populations because of slow action. Field beetles, after treatment with tepa, become sterile within 24 hours. Tepa-treated male beetles are capable of competing sexually with untreated males. Dipping beetles in .0625 tepa solution was as effective as applying 10 µg topically, but reduced the longevity of males 15% and females 29%. Contact of males with tepa-coated surfaces momentarily resulted in a high degree of sterility. Increasing the ratio of fertile to sterile males caused a reduction in fertility that reflected the ratio of fertile and sterile males.

3. European Chafer. In studies with light traps in New York, Electrol-Lads 4500 V-5 ma, and Gardner 3500V-10 ma were ineffective for adult European chafers. Gardner Model 160-30 5000V-30 ma killed 37 to 57% of the chafer that struck the grid. There was an indication that chafer beetles "home-in" on an object silhouetted by the lamp rather than the lamp. A 20-watt black light captured about 6% of the total population of chafer in a tree prior to 11:30 p.m. or about 12% of the population estimated to be present during the entire night. Grid type lights killed about 4 to 6% of the population within a tree.

4. Aphid Traps. At Farmingdale, N. Y., a few more winged aphids were consistently caught in water in pans painted yellow all over than in pans painted yellow on the inside and sandalwood on the outside. Water or a film of grease inside pans trapped equal numbers of aphids but collection of

aphids from greasy films was difficult. The aphid catch was nearly doubled when a wetting agent was added to the water in the traps. In water with detergent, aphids were wetted, sank to the bottom of the pans, and became distorted and unsuitable for taxonomic study quicker than in water only. Federal or safety yellow attracted about 10% more aphids than a lighter yellow in field studies under natural light and in a flight chamber under fluorescent light, and more than a combination of fluorescent and black light.

5. Attractants for Thrips. In Maryland field tests, the color of zinc white paint on a sticky card was the most attractive of several colors to migrating flower thrips Frankliniella tritici Fitch. Other paints in decreasing order of attractiveness were vivid yellow, royal blue, titanium white, bright aluminum, shamrock green, white lead, crimson red, and flat black. Bright aluminum mounted below rose flower buds reduced invading thrips by 75%. Pink, yellow, and white rose blossoms were approximately equal in attractiveness. Deep orange and crimson red were less attractive than pink. Blending of colors in many rose varieties renders color preferences less distinctive.

6. Aluminum Sheets Repel Aphids. In tests in New York, trap catches of flying aphids were reduced 95% by sheets of aluminum coated paper placed on the ground on both sides of rows of gladioluses. Sheets on one side of rows were less effective. Incidence of aphid-transmitted cucumber mosaic virus (CMV) was also reduced by the protective aluminum sheets. Aluminum powder sprays on the soil lacked persistence and on the plants reduced plant growth.

F. Evaluation of Equipment for Insect Detection and Control

In cooperative greenhouse tests in Maryland and New York with low volume mist sprays and thermofogs, one unit (Klip-on fogger) was superior to others tested in that it discharged at high velocity uniformly fine particles of the insecticide for a distance of at least 100 feet in a greenhouse. This or similar mist spraying units are more versatile than thermofog generators and may replace some greenhouse aerosols.

G. Insect Vectors of Diseases.

1. Iris Mosaic. In preliminary studies in Washington, mild iris mosaic symptoms were obtained on seedling iris one year after inoculation by the English grain aphid and Rhopalosiphum padi. The test plants are being retained for another year's growth to see if more definite symptoms appear.

2. Cucumber Mosaic on Gladiolus. In New York, aphid-transmitted cucumber mosaic virus (CMV) in field plots of gladiolus was more serious in late season than in early season plantings, thus showing a distinct seasonal variation in transmission of CMV by its aphid vectors. Development of infections of CMV in gladiolus test plots declined rapidly as the distances

increased from 1 to 20 feet from plots heavily infected with CMV indicating the importance of short distance spread of the virus.

3. Virus Reduced by Aphid Repellant Aluminum Sheets. In small field plots, sheets of aluminum-coated paper placed on the ground on either side of gladiolus rows reduced aphid transmitted CMV (cucumber mosaic virus) infection to 8% and 7% in flowers and plants, respectively, compared to 40 and 37% respectively, in unmulched check rows. A sheet of aluminum on one side of row and aluminum powder spray on the foliage were less effective in reducing CMV infection. Aluminum sprays also reduced size of plant, flower and corm growth.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAM

Basic Biology, Physiology, and Nutrition

Hamilton, D. W. 1964. Periodical cicada, brood size, damage and control. Entomol. Soc. Amer., North Cent. Br. Proc. 19: 141-4.

Hamilton, D. W. 1963. Periodical cicadas in 1963, brood 23. Proc. Ind. Acad. Sci. 72: 167-70.

Henneberry, T. J., Jean R. Adams, and George E. Cantwell. 1965. Fine structure of the integument of the two-spotted spider mite, Tetranychus telarius (Acarina: Tetranychidae). Ann. Entomol. Soc. Amer. 58: 532-5.

Henneberry, T. J. 1964. Effect of host plant nutrition on susceptibility to malathion of two strains of two-spotted spider mites. J. Econ. Entomol. 57: 674-6.

Insecticidal and Cultural Control

Henneberry, T. J., and W. R. Smith. 1965. Malathion synergism against organo-phosphate resistant two-spotted spider mites. J. Econ. Entomol. 58: 312-4.

Jacklin, Stanley W., and Floyd F. Smith. 1964. Late season control of bagworms. J. Econ. Entomol. 57: 769.

Smith, Floyd F., A. L. Boswell, and Stanley W. Jacklin. 1965. Zectran insecticide controls the omnivorous leaf roller, a greenhouse pest. Down to Earth 20: 18, 19, 21, 22.

Smith, Floyd F., and Freeman Weiss. 1965. Pests and diseases--insects and other pests. Chap. 6: 48-71, The Azalea Book, by Frederic P. Lee, 2nd Ed. Van Nostrand Co., N. Y., 433 pp.

Stuart, Neil W., and Charles F. Doucette. 1964. Effects of field applications of toxicants and subsequent storage temperatures on forcing performance of Croft and Ace Easter lilies. The Florists' Rev. Sept. 24, 1964.

Insect Sterility, Attractants and Other New Approaches to Control

Smith, Floyd F., A. L. Boswell, and T. J.Henneberry. 1965. Chemosterilant treatment of two greenhouse spider mites. J. Econ. Entomol. 58: 98-103.

Smith, Floyd F. 1965. Chemosterilant treatment of two greenhouse spider mites. Proc. 12th Inter. Cong. Entomol., London.

Evaluation of Equipment for Insect Detection and Control

Johnson, G. V., A. H. Yoemans, and Floyd F. Smith. 1965. Mechanical aerosol applications in greenhouses. The Exchange CXL 11: 34-7, 60, 69. and Florists' Rev. 135: 31-2, 57-8.

Insect Vectors of Diseases

Bing, Arthur, and George V. Johnson. 1965. The virus questionnaire. N. Amer. Glad. Coun. Bull. 81: 119-20.
Smith, Floyd F., G. V. Johnson, Robert P. Kahn, and Arthur Bing. 1964. Repellency of reflective aluminum to transient aphid virus-vectors. Phytopath. 54: 748.